

LED professional

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Review

LpR 108

March/April 2025

LIGHTING INTERVIEW WITH PROF. LUOXI HAO

STREETLIGHTS: THE FUTURE HUB
FOR SENSORS & COMMUNICATION

THE HIDDEN KEY TO LIGHTING
INDUSTRY SUCCESS

The Global Information Hub
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lightfair
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PAGE 30



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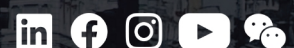
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Exclusive Look at Cutting-Edge Lighting Technologies and Business Strategies



Dear Valued Readers,

The latest edition of LED professional Review (LpR), March/April 2025, #108, is here! This issue is packed with exciting highlights, and I'd like to take a moment to introduce some of them to you.

With LightFair International just around the corner, we are excited to feature it on our cover and provide a brief introduction to this important event. This year, the show is even more compelling with its new partnership, powered by Light + Building—a great reason to attend!

We're also honored to have Dr. Alexander Hoffmann open this issue with his expert commentary on LED technology as a cutting-edge innovation. Our exclusive interview series with the CIE concludes with an in-depth conversation with Prof. Dr. Luoxi Hao, offering insights into the role of lighting education and research.

On the technology front, we explore the latest advancements in Near-Infrared Technology, the state of Micro-Optics, and breakthroughs in GaN technology. Additionally, we dive into two rapidly growing areas: smart street lighting, now equipped with sensors and communication modules, and interoperability in connected lighting systems, with insights from leading experts.

For this issue, we're also stepping beyond our usual technology focus to tackle a pressing business topic: How can lighting companies regain a competitive edge? What inefficiencies exist, and how can they be identified? Industry expert Wojtek Cieplik shares valuable strategies to help businesses thrive.

We hope you enjoy this edition of LED professional Review and look forward to your feedback, thoughts, and ideas. Happy reading!

Yours Sincerely,

A handwritten signature in blue ink, appearing to be 'S. Luger', written over a light blue horizontal line.

Siegfried Luger

Founder & CEO of Luger Research e.U.
Publisher of LED professional, Trends in Lighting, LpS Digital, and the Global Lighting Directory

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- Shipment tracking for all couriers
- Overview of all inquiries, offers, and orders
- Live stock information
- Detailed information on products
- Knowledge panel with interesting content and services

4 EDITORIAL

COMMENTARY

8 LED is Not Just a Light Source – It is High-end Technology!

by Dr. Alexander Hoffmann
Business Line Illumination,
ams OSRAM



NEWS

10 International Lighting News



CIE LIGHTING INTERVIEW

20 Prof. Dr. Luoxi Hao, Vice President Education at CIE

compiled by Editors, LED professional



EVENTS

30 Your Future is Bright at LightFair: The Ultimate Lighting Event You Can't Miss! by LightFair 2025



BUSINESS

32 Enterprise Health: The Hidden Key to Lighting Industry Success

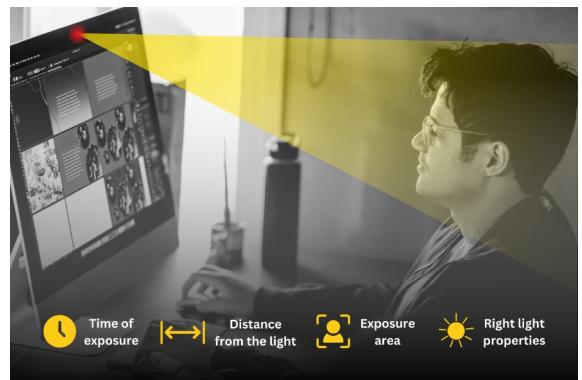
by Wojtek Cieplik, LightGrow Consulting and Brandt & Partners



LIGHTING RESEARCH

38 Near-Infrared Light and Human Health: Exploring the Scientific Foundations and Practical Applications

by Ayhan Siriner, Dr. Anne Berends, and Aleksandra Goncharova



STREET LIGHTING

44 Streetlights Will Become the Location of Choice for Sensors and Communication Modules

by Jonathan Catchpole, TE Connectivity and Martin Creusen, Signify



CONNECTED LIGHTING

48 Understanding and Implementing Interoperability

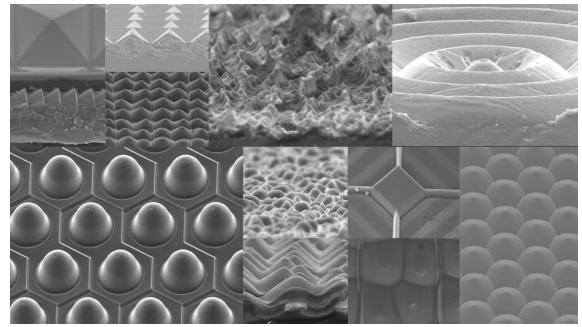
by mwConnect



OPTICS

52 Micro-optics: Shaping the Future of High-Performance LED Lighting

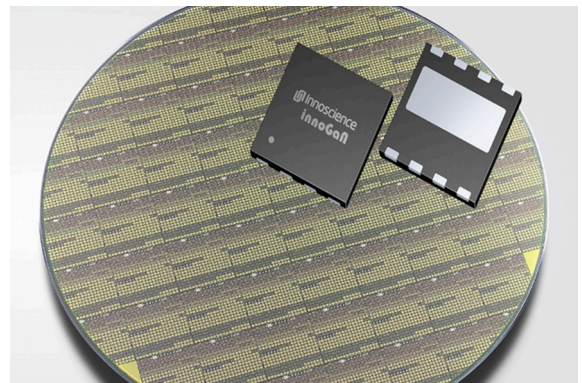
by Jessica van Heck, PHABULOuS



TECHNOLOGY

54 Gallium Nitride (GaN) Technology Brings Efficiency and Size Benefits to LED Lighting Market

by Denis Marcon, Innoscience



LPS DIGITAL TALKS

58 Expert Talks on Light – LUMILEDS

62 ABOUT | IMPRINT



ADVERTISING INDEX

2 Cree LED	15 Cree LED	57 LED professional Review
3 LightFair 2025	17 EPIC	60 Good Light Group
5 Würth	19 LightingEurope	61 DeLighted Talks
9 ams OSRAM	29 CIE	63 Global Lighting Directory
11 Edison	43 Luminus Devices	64 LED professional Review
13 UL Solutions	53 PHABULOuS	



Dr. Alexander Hoffmann
Business Line
Illumination,
ams OSRAM

I have been fortunate enough to accumulate significant experience in the semiconductor industry, which I believe offers exciting opportunities to drive growth and profitability. I enjoy collaborating closely with customers across a variety of sectors, including industrial, lighting, consumer, and automotive, to deliver tailored solutions that meet the dynamic needs of the market. I value the long-term partnerships and sustainable business success that come from these collaborations.

LED is Not Just a Light Source – It is High-end Technology!

ams OSRAM is committed to providing you with the best solution for your business.

Solid market growth

The market will undoubtedly demonstrate robust and sustained growth in the future. We are confident that it will continue to expand at mid-single digit growth through to 2030. This growth is driven by several factors, including increased construction activity worldwide, government regulations restricting inefficient lighting, and government programs aimed at reducing LED lighting costs. We are aware of the challenges currently being experienced by several LED players in the market, which has resulted in their withdrawal. However, we remain committed to our position as a leading provider of outdoor, indoor, horticultural lighting, and industrial solutions, with a focus on performance and quality. I truly believe that the current market developments will enable leading players like ams OSRAM to foster innovation and bring even more value to the customers.

Lower cost per lumen

We are seeing a push for higher efficiency and lower cost per lumen. Miniaturization is key, opening new form factors and applications. Smart lighting with integrated sensors and controls is rapidly gaining traction. ams OSRAM provides its customers with a unique portfolio of innovative LEDs, offering infinite design possibilities, greater cost-effectiveness, outstanding performance, and maximum accuracy – at workplaces, in greenhouses and at home.

Efficiency & Innovation

Energy efficiency is the key priority in outdoor lighting, and LEDs deliver significant savings compared to traditional technologies. We are witnessing the rise of smart street lighting systems, which can be remotely monitored and controlled, ensuring adaptive lighting based on real-time conditions. Light pollution is another concern, driving demand for solutions that minimize upward light spill and glare. Lighting has evolved beyond the simple on-and-off function. With advancements like pixelated lighting, we can now create tailored scenarios that were once unimaginable. We imagine streetlights that project guiding paths for pedestrians, vehicle headlights that display warning symbols like snowflakes on icy roads, and architectural installations that

transform spaces with vibrant, dynamic projections.

We take IP seriously and protect it.

Intellectual Property is one of the pillars of the continuous innovation process. That is why we are committed to defending our protected technologies and ensure that our customers continue to benefit from our products' unmatched quality and performance. Protecting our IP means protecting solutions for our customers. Additionally, by using ams OSRAM-based solutions, our customers can avoid the risk of unauthorized use of ams OSRAM intellectual property, such as potential operational interruptions in their applications. We have monitored multiple cases in this regard and will be taking necessary action in the near future to protect our innovations and your investments.

Horticultural lighting – a step ahead

The world is changing. Cities are growing, farmland is decreasing, the global population is increasing. Indoor farming is becoming more important to meet these demands. LEDs are improving in efficiency and cost-effectiveness, becoming a perfect choice for growers. ams OSRAM is a strong value proposition for OEMs, growers, and consumers. With a significant number of patents, in-house R&D with chip production in Europe, we are leading the way into tomorrow. Our latest OSCONIQ™ P 3737 for horticultural lighting significantly reduces energy costs in greenhouses without compromising on light output ratio (LOR). The LED's market-leading overall wall plug efficiency of 83.2% in Hyper Red allows manufacturers to redesign their fixtures achieving a higher photon flux of 6.13 $\mu\text{mol/s}$ with lower energy consumption, maximizing crop yields and shortening harvest cycles.

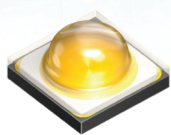
Outlook

We are a global leader in innovative light and sensor solutions. With over 110 years of industry experience, we combine engineering excellence and global manufacturing capabilities with a passion for cutting-edge innovation. We would be delighted to welcome you to our stand at LightFair 2025 in Las Vegas in May or GreenTech in Amsterdam in June 2025, where we hope you will find inspiration for your business. ■ A.H.

High power for high performance.

Choose the **best**.
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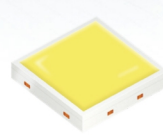
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OSCONIQ® S 5050



DURIS® S 8



OSCONIQ® C 3030

LightingEurope Calls for Full Recognition of Efficient and Intelligent Lighting

lightingeurope.org

The European Commission today presented a package of initiatives: the Clean Industrial Deal, the Action Plan for Affordable Energy and the Omnibus Simplification Package.



While LightingEurope welcomes the efforts to support European industry with the Action Plan for Affordable Energy and to reduce regulatory burdens with the Simplification Package, we regret that energy efficiency technologies, including efficient and intelligent lighting, have been overlooked in the Clean Industrial Deal and that lighting is almost completely absent from the Action Plan for Affordable Energy.

Simplification measures to ease reporting burdens

LightingEurope strongly welcomes the Omnibus Simplification Package, which aims to reduce reporting burdens. The introduction of obligations that are proportionate to the size of the company and its environmental and climate impact is a move in the right direction, especially for SMEs.

"This is an important step to ensure that reporting requirements remain manageable for companies of all sizes," said Elena Scaroni, Secretary General of LightingEurope. "SMEs, which make up a large part of our industry, will benefit from rules that are adapted to their capacity, allowing them to focus on growth and innovation."

LightingEurope will closely monitor the legislative process of this initiative to ensure that the voice of the lighting industry and its SMEs is heard.

Efficient and Intelligent Lighting must be fully recognized in the EU decarbonization pathway

The Clean Industrial Deal aims to support the green transition by promoting clean technologies. However, the deal fails to recognize the critical role of energy efficiency and lighting technologies in contributing to the EU's climate targets.

We welcome the Affordable Energy Action Plan which aims to reduce energy costs, including by incentivizing energy efficiency solutions. We also appreciate the emphasis on the need for better enforcement of product rules, including online. We regret that the proposed actions do not seem strong enough at this stage and that the role of renovation and smart and efficient lighting is almost completely overlooked.

"Efficient and intelligent lighting is an immediately available and cost-effective solution to reduce energy consumption and CO₂ emissions," said Teresa Selvaggio, Director of Public Affairs of LightingEurope. "To meet Europe's decarbonization targets, efficient and intelligent lighting must also benefit from the support mechanisms outlined in the Clean Industrial Deal and the Affordable Energy Action Plan to complete the transition to LEDs, starting with the renovation of public buildings."

LightingEurope urges policymakers to ensure that all clean technologies, including efficient and intelligent lighting receive adequate support.

Contact: Elena Scaroni, Secretary General
<mailto:elena.scaroni@lightingeurope.org>

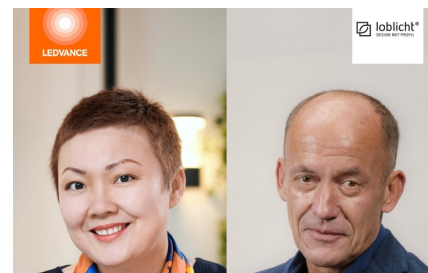
About LightingEurope

LightingEurope is the voice of the lighting industry, based in Brussels and representing 32 companies and national associations. Together these members account for over 1,000 European companies, a majority of which are small or medium-sized. They represent a total European workforce of over 80,000 people and an annual turnover exceeding 15 billion euro. LightingEurope is committed to promoting efficient lighting that benefits human comfort, safety and well-being, and the environment. LightingEurope advocates a positive business and regulatory environment to foster fair competition and growth for the European lighting industry. ■

LEDVANCE Expands Brand Portfolio with Acquisition of German Lighting Company loblicht

www.loblicht.de

LEDVANCE, a global leader in lighting solutions, is pleased to announce the acquisition of loblicht, a German lighting expert renowned for high-quality design products. This acquisition marks a significant milestone in LEDVANCE's mission to strengthen its lighting project expertise and its portfolio of brands.



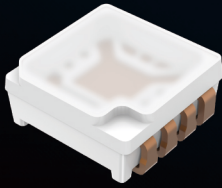
Jue Wang, LEDVANCE Executive Senior Vice President (left) and Thomas Kretzer, loblicht Managing Director (right).

loblicht's longstanding reputation for excellence and innovation has made it a trusted partner of LEDVANCE for years. The acquisition reflects LEDVANCE's commitment to meeting the needs of its project customers and enabling them to harness the power of light.

"We are thrilled to officially welcome loblicht into the LEDVANCE family. loblicht has been a valued partner for years, and this acquisition is a natural progression of our successful relationship. Over the past years, we have established LEDVANCE as the partner of choice for lighting projects. The acquisition of loblicht will strengthen our portfolio of powerful product brands. Their exceptional expertise and network in the project business, together with their reputation for high-quality products, will enhance our capabilities. It underscores our commitment to delivering sophisticated and top-quality products to our customers", said LEDVANCE Executive Senior Vice President Jue Wang.

loblicht, based in Arnsberg, North-Rhine Westphalia, implements high-end luminaires for workspaces, modern office landscapes and public spaces. The loblicht system solutions bring to life architecture and light through a product range with harmonized variations, versatile components and modern features. loblicht, known at the time as tecnolight, was acquired by HTP Maximum GmbH in 2020, a holding company based in Düsseldorf, Germany that invests in majority shareholdings of German SMEs. "Even if selling companies is not our DNA, we immediately saw the long-term strategic value that could be unlocked in bringing loblicht into the LEDVANCE family. And we are thrilled that our mission in establishing loblicht as a new premium lighting brand and securing jobs here in Arnsberg was successful," said Patrick Nathe, CEO of HTP. Following its acquisition by LEDVANCE, loblicht will become a fully owned subsidiary of LEDVANCE.

"LEDVANCE's global footprint and customer network, in combination with loblicht's deep level of expertise in lighting projects, opens exciting new growth opportunities for the loblicht brand. We are excited to leverage the synergy between our organizations to bring even greater value to our customers.



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Together, we will build on our collective strengths, fostering innovation and creating new possibilities in the lighting industry”, said loblicht Managing Director Thomas Kretzer.

About loblicht

The loblicht GmbH DESIGN MIT PROFIL is a young, experienced company in the lighting industry based in Neheim Arnsberg, Sauerland. loblicht designs, develops, and manufactures high-quality lighting solutions for work environments and nearly all architectural interiors. The brand represents sophisticated lighting solutions, offering a wide range of pre-configurable ceiling lights, floor lamps, downlights, and light channels that provide ample design flexibility. An enthusiastic team creates lighting solutions with exceptional quality and practical value. loblicht is a reliable and fair partner for both customers and suppliers. ■

Signify Announces That CEO Eric Rondolat Will Step Down After the AGM 2025

www.signify.com/

Signify announced that CEO Eric Rondolat will step down from the company's Board of Management after the Annual General

Meeting of shareholders (AGM) to be held on April 25, 2025.

Eric Rondolat has held the position of Chief Executive Officer and Chair of the Board of Management at Signify since the company was listed on the Euronext Amsterdam stock exchange in May 2016. Before that, he was Executive Vice President and Chief Executive Officer for Lighting at Philips from April 2012 to May 2016.

The Supervisory Board and Eric Rondolat have agreed that the time is right for a change of leadership. The Supervisory Board will now conduct the search for a successor and will consider both internal and external candidates.



Eric Rondolat.

“It has truly been a great honor for me to lead this exceptional company through the demanding transformation of the lighting industry. I am immensely proud of what our teams have achieved, building the industry

leader in a new technological era. Together, we have developed a culture of responsible innovation and set new benchmarks for sustainable growth, while enhancing our teams' solidarity and customer centricity,” said Eric Rondolat, CEO of Signify. “As we conclude this important chapter of our transformation, I am very confident that Signify will continue to lead and successfully execute its growth strategy. While the Supervisory Board conducts its search, I remain more than ever committed to my colleagues, our customers, investors and other stakeholders.”

“On behalf of the Supervisory Board, I would like to express our gratitude to Eric for his vision and dedication, as he led the business for more than twelve years,” said Gerard van de Aast, Chair of the Supervisory Board of Signify. “Under his leadership, Eric successfully delivered the company's separation from Philips and IPO, continually establishing Signify as the global leader in lighting for professionals and consumers. His experience and unrivalled knowledge of the market have been essential to successfully navigating the challenging and dynamic market conditions of recent years. His foresight led to the transformation of the business to LED and connected lighting technologies. In doing so, he has set the course for Signify to continue to lead the lighting industry through the digital age. We are pleased that Eric will remain with the business until the AGM 2025.” ■

onsemi Proposes to Acquire Allegro MicroSystems for \$35.10 Per Share in Cash

www.onsemi.com

onsemi (NASDAQ: ON) today disclosed details of a proposal submitted to the Board of Directors of Allegro MicroSystems, Inc. ("Allegro") (NASDAQ: ALGM) to acquire the company for \$35.10 per share in cash for each share (the "Proposal") of Allegro's common stock on a fully diluted basis at an implied enterprise value of \$6.9 billion.



onsemi has made numerous attempts over the past six months to enter into constructive discussions regarding a potential transaction. The most recent Proposal was submitted to Allegro on February 12, 2025, and represents an increase over an initial \$34.50 per share proposal submitted on September 2, 2024.

"We believe the combination of onsemi and Allegro would bring two highly complementary businesses together, benefitting our respective customers and delivering immediate value to Allegro shareholders," said Hassane El-Khoury, President and Chief Executive Officer of onsemi. "The Allegro team has built an impressive leadership position in magnetic sensing and power ICs for the automotive and industrial end-markets. Together, Allegro's unique product portfolio and onsemi's differentiated intelligent power and sensing technologies would create a diversified leader in automotive, industrial and AI data center applications."

El-Khoury continued, "While we would have preferred to reach an agreement with Allegro privately, the decision to make our proposal public reflects our conviction in the merits of a combined company, which we believe is in the best interests of Allegro and onsemi shareholders. We urge the Allegro Board and management team to engage in good faith discussions with onsemi's management team regarding the proposed transaction, which maximizes value for Allegro shareholders."

The combination between onsemi and Allegro would create a natural strategic fit given both parties' respective strengths within the automotive and industrial markets:

Compelling Strategic Rationale That Delivers Benefits for Customers and Employees:

Allegro's product offering complements onsemi's leadership in intelligent power and sensing for automotive, industrial and AI data center applications. A combination would bring together two strong teams with a shared culture of innovation and access to exciting new development opportunities within an expanded organization.

Delivering Immediate and Certain Value for Allegro Shareholders: Under the terms of the Proposal, onsemi's all-cash \$35.10 per share offer represents a 57% premium to Allegro's closing share price on February 28, 2025, the last trading day prior to media reports regarding onsemi's interest in acquiring Allegro.

Clear Path to Completion and Plan for Financing: onsemi has assembled a team of highly experienced advisors and is prepared to move swiftly and efficiently to complete due diligence and negotiate a mutually agreeable definitive agreement. The company does not anticipate any financing contingencies and intends to fund the potential transaction with a combination of committed financing, cash on hand, and funds available under its existing revolving credit facility.

Engagement History

onsemi first approached Allegro regarding a potential all-cash acquisition on September 2, 2024, via a formal letter with an initial all-cash \$34.50 per share proposal. A follow-up letter was sent December 10, 2024, reaffirming onsemi's desire to transact and gain access to find a pathway to diligence. Subsequently, onsemi made another attempt towards constructive engagement, most recently submitting a letter on February 12, 2025, improving its all-cash proposal to \$35.10 per share, while also highlighting its numerous efforts to meaningfully engage with Allegro.

onsemi's request since September 2, 2024, has been consistent: to advance the possibility of this valuable outcome for shareholders through rigorous management-to-management dialogue and pursuing the requisite diligence and scoping of regulatory requirements in order to expeditiously move towards finalization of a transaction. ■

ams OSRAM Receives EU Commission Approval for an Investment Grant up to EUR 227 million

ams-osram.com

The European Commission today approved funding for a semiconductor manufacturing facility for ams OSRAM AG (SIX: AMS) under

the European Chips Act. The official funding approval from the Austrian Ministry of Economy and Labor, which is responsible for the payment of the funding, is now expected shortly. ams OSRAM plans to use the funding of up to €227 million approved by the European Commission to sustainably strengthen the development and production site in Premstaetten. In total, the company plans to invest 567 million euros in the project by 2030, when full production will begin at the headquarters in Styria.



"We are pleased that the European Commission has approved Austrian state aid under the European Chips Act to expand our semiconductor manufacturing in Premstaetten," said Aldo Kamper, CEO of ams-OSRAM AG. "The financing is part of ams OSRAM's important investments in Austria in new generations of innovative microchips for medical and automotive applications. The first fab of its kind for next-generation optoelectronic sensors is a key cornerstone of our growth strategy. In line with the objectives set out in the European Chips Act, it will strengthen Europe's security of supply and technological autonomy in the field of semiconductor technologies. We are grateful for the support we have received from both the Austrian government and the European Commission."

The new plant at the production site in Premstaetten is intended to further expand the leading role of the Austrian semiconductor industry. In the future, the semiconductor manufacturing facility will produce highly differentiated next-generation optoelectronic sensors that are qualified for applications in medical technology and the automotive industry. In addition, the production of products for industry or for use in consumer goods is planned. It combines outstanding technologies (CMOS, filter¹ and TSV²) and works according to a toolbox concept. Depending on the product, the different capabilities can be combined individually as required for energy-efficient products for imaging and optoelectronics with a reduced form factor, more functions on a single component and outstanding electrical performance. The construction of the additional cleanroom at the Premstaetten site, with an area of 1,800 square meters for CMOS production, will also double filter capacity and increase TSV capacity by a factor of four.

In view of the global situation in the semiconductor market, it is clear how important it is to invest in innovative key technologies for the future. That is why the European Commission has set itself the goal of promoting the mass production of semiconductors in Europe and increasing the global market share to 20 percent of production by 2030. In addition, new chip technologies for the next generation are to be made possible. The European Chips Act was created for this purpose. The investment of ams OSRAM will help to strengthen European sovereignty in semiconductor production and digitalization. It will also make an important contribution to the green transition.

1) Filters select incoming radiation. For example, they use the phenomenon of interference - the overlapping of light wavelengths - to pass or reflect certain spectral ranges of electromagnetic radiation. This enables color recognition beyond that of the human eye, 2) TSVs - Through Silicon Vias - are vertical electrical connections through a chip. They are essential building blocks for advanced packaging technologies for high performance, small footprint devices required in many different market segments such as consumer, automotive, medical, etc. Devices with TSVs are typically 30 to 70 percent smaller than conventional packaging concepts. Such a significant reduction in size is necessary to enable the implementation of sensors in Internet of Things applications.

About ams OSRAM

The ams OSRAM Group (SIX: AMS) is a global leader in innovative light and sensor solutions. With more than 110 years of industry experience, we combine engineering excellence and global manufacturing with a passion for cutting-edge innovation. Our commitment to pushing the boundaries of illumination, visualization, and sensing enable transformative advancements in the automotive, industrial, medical, and consumer industries.

“Sense the power of light” – our success is based on the deep understanding of the potential of light and our distinct portfolio of both emitter and sensor technologies. Approximately 19,700 employees worldwide focus on pioneering innovations alongside the societal megatrends of digitalization, smart living and sustainability. This is reflected in over 13,000 patents granted and applied. Headquartered in Premstaetten/Graz (Austria) with co-headquarters in Munich (Germany), the Group achieved EUR 3.4 billion revenues in 2024 and is listed as ams-OSRAM AG on the SIX Swiss Exchange (ISIN: AT0000A3EPA4).

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Sustainability in Emergency Lighting: The Role of TM65 and TM66 Explained

www.ventilux.com/

As sustainability continues to shape the construction and lighting industries, it is crucial for electrical contractors to understand key environmental assessment methodologies. Two important technical memorandums - TM65 and TM66, play a significant role in evaluating the environmental impact of lighting products. However, they serve distinct purposes.



Ian Murphy, R&D Manager at Ventilux Ltd.

What are the differences between TM65 and TM66, their relevance to emergency lighting, and how do they compare to Environmental Product Declarations (EPDs)?

TM65 is a method for calculating the embodied carbon of building services products, including luminaires, heating systems, and other mechanical and electrical components. It provides an estimate of a product's carbon footprint when a full Environmental Product Declaration (EPD) is not available.

For emergency lighting manufacturers like Ventilux, TM65 is particularly relevant because their customers, including electrical contractors and consultants, often require embodied carbon calculations to assess the sustainability of projects. The TM65 framework considers the materials used in the product's construction, the manufacturing processes and energy consumption, the transportation from production to the point of use, and the installation impacts on-site.

TM66 is different, it is a lighting-specific framework designed to promote a circular economy in the lighting industry. Unlike TM65, which quantifies embodied carbon, TM66 provides guidance and an assessment methodology to evaluate how well lighting

products align with circular economy principles.

TM66 focuses on design for circularity, ensuring products are easy to disassemble and repurpose. It also emphasizes remanufacturing potential to extend product life cycles and recycling efficiency by using sustainable materials. Additionally, TM66 promotes effective end-of-life management, aiming to reduce landfill waste. While TM66 does not provide direct data for embodied carbon calculations, it demonstrates a company's commitment to sustainability and responsible product design. Overall, while TM65 is valuable for project specifications, TM66 highlights a company's broader, long-term commitment to environmental responsibility.

An Environmental Product Declaration (EPD) is a comprehensive third-party-verified document that provides a full Life Cycle Assessment (LCA) of a product, covering its entire environmental impact from raw material extraction to disposal.

What many people don't realize is that the third-party verification process that ensures accuracy, can differ with each different program operator who then oversees their registration and publication – often meaning different or conflicting calculations. While TM65 and TM66 provide valuable insights, they are not full LCAs like EPDs. However, when used together, TM65 and TM66 data can give a detailed picture of a product's sustainability, making them a useful alternative when an EPD is not available.

Ventilux are committed to providing reliable TM65 data to assist their customers with embodied carbon calculations. Additionally, they support TM66 principles as part of their mission to drive sustainability within the emergency lighting sector.

Ian Murphy, R&D Manager at Ventilux Ltd, emphasizes the company's dedication to environmental responsibility: "At Ventilux, sustainability is embedded in everything we do, so much so we've made efforts to remove all non-essential plastic from our packaging. We also take proactive steps to reduce embodied carbon using TM65 and champion a circular economy with TM66. We believe that by embracing both, we are setting standards in the emergency lighting industry and helping our clients make more responsible choices."

By understanding these frameworks clients and contractors can make more informed choices when selecting products, ensuring compliance with sustainability goals and regulatory requirements.

About Ventilux

Ventilux designs, manufactures and offers an extensive range of safety system products

and services, including Emergency Lighting, Central Battery Systems, Luminaire Conversion Equipment, Emergency Lighting Commissioning, Service and Maintenance. Ventilux was founded in 1986, and has since grown steadily to become one of the largest Independent Emergency Lighting Manufacturers in Europe & the Middle East.

The Head Office in Bray, Co.Wicklow, Ireland, is the center of the Ventilux operation, with over 35,000 sq. ft. of state-of-the-art production facilities, research and development laboratories, in house training center and global distribution warehouse. Liverpool is the UK base for distribution, sales order processing and in-house conversions.

Ventilux operate, and are certified to, ISO: 9001:2015. Modern manufacturing technology combined with stringent quality control ensures that Ventilux products provide the customer with top quality and excellent value for money. In Ventilux we have a highly experienced and talented R&D Department who are consistently designing products that reduce contractors' project costs and also reduce our clients' day-to-day costs. ■

Cree LED Advances Horticulture Lighting with Launch of XLamp XP-L Photo Red S Line LEDs

www.cree-led.com

Cree LED®, a Penguin Solutions brand (Nasdaq: PENG), has introduced the new XLamp® XP-L Photo Red S Line LEDs, a groundbreaking advancement in horticulture lighting technology. Designed to deliver exceptional efficiency, exceptional durability and seamless system upgrades, these LEDs are optimized for high-performance applications in greenhouses, vertical farms, and other large-scale growing operations.



The XP-L Photo Red S Line LEDs represent a 6% improvement in typical Wall-Plug Efficiency (WPE) over the previous generation, reaching 83.5% at 700 mA and 25°C. This improvement offers compelling cost benefits for horticulture customers. They can reduce operating costs by upgrading to the same output with less power consumption or lower initial costs with a redesign that reduces the

necessary number of Photo Red LEDs by up to 35

Built with advanced S Line technology, Cree LED's XP-L Photo Red LEDs deliver top-tier sulfur and corrosion resistance, extending their lifespan and ensuring reliable performance. These features significantly reduce maintenance costs while providing consistent, high-quality lighting throughout critical growth cycles. Additionally, with the same 3.45 x 3.45 mm XP footprint as the XP-G3 Photo Red S Line LEDs, the XP-L Photo Red enables seamless upgrades to existing designs.

"Our new XP-L Photo Red S Line LEDs combine the efficiency and durability our customers demand with our popular XP package design for ease of adoption," said Joe Clark, president, Cree LED. "Along with our extensive portfolio of optimized solutions, these LEDs are an ideal choice for many horticulture lighting applications."

Product samples are available now, and production quantities are available with standard lead times. To learn more, visit www.cree-led.com/news/xlamp-xpl-photored/.

Cree LED and XLamp are registered trademarks of CreeLED, Inc. All other trademarks and registered trademarks are the properties of their respective owners.

About Cree LED

Cree LED, a Penguin Solutions brand, offers one of the industry's broadest portfolios of application-optimized LED chips and components, leading the industry in performance and reliability. With more than 35 years of innovation, our strong IP portfolio and unique business model ensures supply chain continuity. We deliver best-in-class technology and breakthrough solutions for focused applications in high power and mid-power general lighting, horticulture, specialty lighting and video screens. For more information, visit cree-led.com. ■

Nichia Launches White LED "NS2W806H-B2" Featuring Blue/Green Chips

<https://led-ld.nichia.co.jp/en>

Nichia, the world's largest LED manufacturer and inventor of the high-brightness blue and white LED, is launching a white LED (Part No. NS2W806H-B2) designed for LCD backlighting. This product adds a new green chip in addition to the existing blue chip, resulting in a configuration that combines both blue and green within a single package.

For LEDs used in LCD backlighting, it is common to achieve white light by combining a

Upgrade Performance with J Series® JB3030C 3V E Class Pro9™ White LEDs

Cree LED's high-performance **JB3030C 3V E Class Pro9 White LEDs**, designed for maximum efficiency and versatility, offer up to 233 LPW at 4000K, 80 CRI; **up to 13% higher LPW at 90 CRI; compatibility with 301B/H; and 6500K-2700K CCT in 80 & 90 CRI**, delivering flexibility for indoor lighting applications.



www.cree-led.com

blue chip with green and red phosphors. However, due to the significant performance improvements in Nichia's green chip, the NS2W806H-B2 uses a green chip instead of the green phosphor, enabling a white LED with a peaky and narrow green spectrum.

The peaky and narrow green spectrum is highly compatible with color filters, resulting in improved efficiency as an LCD module. Additionally, it enables a wider color reproduction not only for green but also for red. This innovation allows for both wide color gamut and high brightness/low power consumption without any trade-off, while also ensuring reliability.

With this groundbreaking technology, Nichia expects to contribute to the development of next-generation visual devices such as monitors that require beautiful color reproduction, mobile displays that demand both low power consumption and wide color reproduction, and automotive displays requiring high reliability and visibility, all of which conventional backlight technology has faced challenges in the past.

Nichia continues to develop products that are useful to society. ■

Refond Launches Industry-First Diamond-based Ultra-high Power Density Packaging

www.refond.com

In the traditional LED lighting field, heat dissipation has always been a critical factor limiting performance improvement. Especially with the rapid development of LED technology towards high luminous efficiency and high power, high-power LED packaging

technology, due to its structural and process complexity, directly affects the performance and lifespan of LEDs. In complex application scenarios, high-power LEDs face issues such as accelerated light decay and reduced stability caused by poor heat dissipation, which have become urgent challenges for the industry.

To address the pain points of traditional high-power packaging products, Refond has innovatively adopted diamond-based substrate technology, launching a groundbreaking high-power packaging product—Diamond-based Ultra-high Power Density Packaging. This product meets the demand for high-power LEDs in scenarios such as automotive headlights, outdoor high-intensity lighting, and stage lighting, opening up more possibilities for the development and application of high-power LEDs.

01 High Thermal Conductivity, Superior Heat Dissipation Performance

In high-power application scenarios such as automotive headlights, conventional ceramic materials often suffer from severe light decay, shortened lifespan, or even burnout due to poor heat dissipation. Refond has innovatively adopted a diamond-based substrate, with a thermal conductivity of up to 1800W/(m·K), which is 10 times that of ceramic materials. This enables continuous brightness improvement under high power while ensuring the LED chip operates stably at higher power levels.

02 Compact Single-Lamp Size, High Luminous Efficiency

The new product offers a variety of specifications, with the smallest single-lamp size measuring just 5*5mm. It is fully compatible with mainstream market standards, allowing direct replacement of existing solutions, effectively reducing maintenance costs. It meets the requirements of various high-efficiency application

scenarios, especially suitable for situations requiring high brightness and long-term illumination, such as streetlights.

03 High Single-Lamp Power, Excellent Optical Performance

In terms of optical performance, Refond has significantly reduced light propagation losses through the innovative design of the diamond-based substrate packaging structure. The single-lamp power can reach 60W, with a luminous flux exceeding 6500lm. The light distribution is brighter and more uniform, delivering outstanding optical performance in scenarios requiring high brightness and uniformity, such as projectors.

04 Advanced Packaging Technology, Higher Reliability

Diamond material has a low thermal expansion coefficient, which reduces thermal stress caused by temperature changes and prevents issues such as cracking or delamination. Refond's diamond-based ultra-high power density packaging utilizes proprietary advanced packaging technology, effectively enhancing the reliability, stability, and lifespan of the device. This characteristic is particularly important in professional lighting scenarios such as stage lighting, ensuring excellent performance even under high-intensity operation.

Innovation Drives the Future: Explore & Infinite

The launch of the new diamond-based ultra-high power density packaging product is undoubtedly a significant breakthrough in the lighting field. It brings a qualitative improvement to current lighting applications and injects new vitality into the development of high-end lighting. It is gradually demonstrating immense potential in applications such as outdoor lighting, automotive lighting, drone lighting, projectors, and stage lighting.

Relying on its innovative breakthroughs in ultra-high power density packaging technology, Refond will continue to drive product upgrades and iterations, further enhancing the competitiveness of its products to meet the market's diverse application demands for high-efficiency, high-performance LED light sources. ■

KUMUX and K-array Transform Spaces with Well-being-centered Technology

kumux.io/

KUMUX, a leader in science-based dynamic lighting solutions, is pleased to announce its collaboration with K-array, a manufacturer of combined professional lighting and audio systems. This alliance marks a milestone in dynamic work environments focused on human well-being.



Traditional artificial lighting does not always meet people's biological needs. Aware of this, KUMUX has developed software based on artificial intelligence that adapts lighting to circadian rhythms, providing a more natural and health-beneficial lighting experience. When integrated with RAIL by K-array, an innovative architectural line that combines light and sound in a single product, a multisensory environment enhances comfort, creativity, and workplace performance in a convergence of design.

"In a world where we spend most of our time indoors under static lighting, the incorporation of KUMUX into RAIL by K-array allows workspaces to align with natural light rhythms, promoting well-being, mood, and productivity," explains Adria Huguet, CTO of KUMUX. "This collaboration is the perfect combination of lighting, intelligent control and science, offering a solution that reconnects people with the light cycles they truly need."

RAIL by K-array, with its sleek design and ability to integrate professional sound and personalized lighting, has been the choice for innovative international projects such as the office renovations of Pavion, JLL, and Armstrong Ceilings, as well as the redefinition of modern workspaces led by TAD Associates. Due to the incorporation of KUMUX technology, this system now optimizes the auditory and aesthetic experience of spaces and contributes to the health and well-being of its occupants.

With the rise of certifications such as WELL Building Standard and the growing recognition of the influence of light and sound on human behavior, this alliance between KUMUX and

K-array represents a crucial step towards creating the indoor spaces of the future.

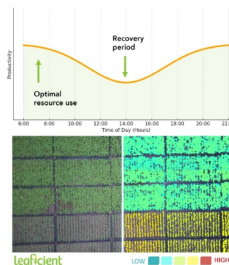
"Our mission is to facilitate the implementation of intelligent solutions that improve people's daily lives in their workplaces. With RAIL, we offer unprecedented integration of audio and circadian lighting, ensuring healthier and more productive environments with ease," concludes Huguet.

This collaboration reaffirms KUMUX and K-array's commitment to innovation and the design of spaces that prioritize human well-being. With technologies that mimic natural light and enrich the sound environment, the building of the future is now a tangible and accessible reality. ■

Sollum Technologies and Leaficient Introduce the First Plant-responsive Dynamic LED Lighting Solution

www.sollumtechnologies.com

Sollum Technologies and Leaficient are pioneering a breakthrough technology that redefines how LED lighting adapts to plant growth. Today's traditional lighting strategies rely on Daily Light Integral (DLI) as the primary metric for optimizing plant growth, based on the premise that plants absorb and use light with the same efficiency throughout the day and at all growth stages. However, recent research has shown that plant productivity can change significantly based on a myriad of factors relating to the environment, resources provided and internal biological processes. In response, Sollum and Leaficient are collaborating to develop the first closed-loop, plant-adaptive dynamic lighting system, which adjusts lighting in real time based on plant productivity and growth rates.



"Today's lighting strategies are outdated because they don't take into account the actual efficiency of light absorption by plants," said François R-Moisán, CTO and co-founder of Sollum Technologies. "Growers are often paying for photons that plants are not using effectively. By integrating Leaficient's real-time plant measurement technology with our dynamic LED lighting solution, we can now ensure that every photon is maximally

utilized—boosting yields while reducing energy costs."

A new era in dynamic lighting
The combined Sollum-Leaficient solution leverages Leaficient's cutting-edge plant monitoring technology to measure photosynthetic efficiency and adjust light intensity accordingly. This closed-loop approach ensures that plants receive the exact amount of light they need, precisely when they need it, eliminating unnecessary energy costs and optimizing growth conditions for any crop varieties.

"The future of horticultural lighting isn't just about delivering more light—it's about delivering the right light at the right time," said Brian Stancil, co-founder and CEO of Leaficient. "By focusing on real-time plant productivity rather than static lighting schedules, we're not just improving efficiency—we're transforming how growers manage their crops."

This groundbreaking collaboration between Sollum and Leaficient marks a paradigm shift in controlled environment agriculture with the first plant-aware dynamic lighting solution that maximizes both yield and sustainability.

Industry disruption with real-world impact
For greenhouse and vertical farm operators, this innovation offers a compelling alternative to legacy lighting strategies that often rely on static schedules and overcompensate with excessive energy consumption. Instead, Sollum and Leaficient offer an intelligent lighting system that adapts to the biological rhythms of crops to ensure optimal performance at every stage of development. Beyond optimizing lighting efficiency, this breakthrough will enable precise control over crop development—triggering fruiting and flowering at optimal times or even enhancing specific nutrient and flavor profiles.

About Sollum Technologies
Sollum Technologies designed the only 100% dynamic LED lighting solution that modulates the full spectrum of the Sun's natural light to illuminate closed environments such as greenhouses, research centers and laboratories. Sollum's award-winning, turnkey solution consists of internet of things, AI-powered light fixtures that are controlled by Sollum's proprietary SUN as a Service® cloud platform. Sollum's distinctive proposition is a fully scalable cleantech solution that evolves with business needs and multi-zone light management, with each zone benefiting from automatic dimming of an unlimited number of light recipes; this is why it provides unparalleled value in terms of energy savings and, additionally for greenhouse growers, increased productivity, and superior produce quality.

Founded in 2015, the company is headquartered in Montréal (Québec, Canada),



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where its design, development, and manufacturing activities are concentrated, and has representative offices in Leamington (Ontario, Canada) and Atlanta (Georgia, US). For more information, visit sollum.tech.

About Leaficient

Leaficient is redefining agriculture with innovative AI-driven solutions. Its flagship platform, HeliOS, combines remote sensing and predictive AI with grower-centric design to deliver actionable insights and enhance productivity. By bridging the gap between AI and farming, Leaficient is empowering growers worldwide to thrive in a sustainable, data-driven future.

Leaficient is headquartered in Pittsburgh, Pennsylvania, a hotbed for robotics and AI innovation. The core technologies behind Leaficient's solution were developed with support from the National Science Foundation and Carnegie Mellon University. ■

PixNet Control Launch New and Improved PixNet Mini V2 for Even Greater LED Lighting Control

pixnetcontrol.com

Lighting and LED control specialists, PixNet Control, have recently launched a second-generation of their leading compact LED lighting controller, PixNet Mini, complete with new features. Building upon the original model, the PixNet Mini V2 is a compact device that controls multiple LED lights, configuring their brightness and color to create captivating displays, visual effects and animations.



Pi

Now with PoE (Power over Ethernet), the PixNet Mini V2 gives AV (Audio-Visual) installers more versatility within their lighting installations, with added options for powering their LED controller device.

It also has a newly added grouping feature, enabling users to connect multiple different pixel protocols on the same data line, simplifying complex installations and improving synchronization across diverse lighting setups.

“As LED experts committed to pushing the creative capabilities of lighting displays, we’re

pleased to be enhancing our small yet powerful LED controller with new features and functions. The addition of PoE and grouping makes the PixNet Mini V2 even more of an indispensable tool for creating a captivating lighting setup” says Alan Reeves, CEO of PixNet Control.

LED controllers like the PixNet Mini by PixNet Control are widely used by AV installers across the UK to create and configure complex LED lighting displays for events, nightclubs, theatres, gyms and more.

The original PixNet Mini was released in 2024 to provide more flexibility for PixNet Control's customers, offering the same power and creative capabilities as their standard LED controllers, but in a more compact size for discreet installations.

The PixNet Mini features advanced network-based firmware updates and configuration options, enabling seamless remote management, system adjustments and real-time optimization for ultimate performance.

“Designed for use in demanding lighting setups, the PixNet Mini LED controller has the capacity to control up to eight lighting universes, each with up to 1,360 LEDs at a refresh rate of 25Hz for smooth and responsive effects. In repeat mode, it can support up to 9,520 LEDs! For broader LED support, the PixNet Mini V2 includes a DMX512 input/output port, meaning it's compatible with industry-standard digital multiplex devices or DMX-compatible LED chips” adds Alan.

Based in North Walsham in Norfolk, PixNet Control have led the way in LED lighting control innovations for nearly 15 years. Their products power prestigious projects, from iconic London events to major television and theatre productions.

With extensive expertise in specialized lighting and a robust network of industry connections, PixNet Control are a key player in the lighting installation sector due to the technical support and consultation services they provide.

“We take great pride in empowering AV installers and lighting designers to bring their creative visions to life. The PixNet Mini V2 not only pushes the boundaries of LED control technology but also underscores our dedication to developing advanced tools that enable stunning visual displays” concludes Alan.

For more information on the new PixNet Mini V2, visit <https://pixnetcontrol.com/pixel-controllers/74-pixnet-mini-.html> ■

Ultra-Narrow Beam UV LEDs with Exceptionally Focused 10° Beam for High Intensity and Collimation Applications

violumas.com/

Violumas, provider of high-power UV LED solutions and inventor of 3-PAD LED technology, has launched an ultra-narrow beam UV LED product suitable for collimation, focused illumination, long distance, and fiber coupling applications. With an integrated 10° fused silica optic, the VioBeam-1X1 achieves high intensities at extended distances, allowing for the reduction of LEDs in high-dosage systems. The LED is available in 255nm, 265nm, 275nm, 295nm, and 310nm wavelengths and ready for direct integration.



Violumas aims to provide the best variety of high-performance UVA, UVB, and UVC LEDs, encapsulated with the highest quality fused silica optics. The wide selection of beam angles (30°, 60°, 90°, 120°, and 135°) allows Violumas to provide unique solutions specifically tailored to any UV LED application. The newest addition to the product line, the VioBeam-1X1 series, offers an unprecedented ultra-narrow 10° beam combined with a high-power UV LED, opening opportunities for new developments in ultraviolet applications.

The VioBeam-1X1 series is available in 255nm, 265nm, 275nm, 295nm, and 310nm wavelengths and delivers up to 0.1W optical output. The integrated 10° optic maximizes UV light in a small target area and is ideal for long-distance transmission with high intensity requirements. Compared to a typical 135° flat window, the VioBeam-1X1 can emit up to 55x higher intensity in a small spot size of 10x10mm at 50mm distance, thereby achieving high dosage targets with less LEDs.

With 5 UVB/UVC wavelength options, the LED's impressive far-field intensity and focused spot illumination can be utilized for applications in life sciences, water disinfection, curing, spectroscopy, environmental monitoring, air purification, research, and more. ■

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From Research to Impact: CIE's Role in Global Lighting Education – Prof. Dr. Luoxi Hao, Vice President Education at CIE



Prof. Dr. Luoxi Hao:

“The future of lighting education will be multidisciplinary, technology-driven, and application-oriented, continuously integrating emerging innovations to cultivate professionals who can lead the next wave of advancements in the field.”

In this exclusive interview, Prof. Dr. Luoxi Hao, Vice President of Education at CIE, shares her inspiring journey from an academic researcher to a global leader in lighting education. With decades of experience in architectural lighting, research, and international collaboration, she discusses the evolving role of education in the lighting industry, the impact of emerging technologies, and how CIE is shaping the future of lighting standards worldwide. Professor Hao also highlights key skills for aspiring professionals, the significance of human-centric lighting, and the importance of interdisciplinary learning. Her insights offer a compelling vision for the next generation of lighting experts.

www.cie.co.at

LED professional: First of all, we would be interested in hearing about your career path and how you ultimately became the Vice President Education at CIE

Prof. Dr. Luoxi Hao: In 1995, I was pursuing a Ph.D. in the Department of Architecture at the College of Architecture and Urban Planning, Tongji University, Shanghai, China. My dissertation, *Non-Quantitative Design Research on Visual Environments*, focused on the subjective and qualitative aspects of lighting design. My advisor, Professor Gongxia Yang, was one of the few Chinese professors of that era with strong English proficiency. I still remember our discussions, where he emphasized the importance of studying technical publications from the International Commission on Illumination (CIE), which became essential references for my research.

After completing my Ph.D., I continued my academic journey as a postdoctoral researcher at the School of Architecture, Tsinghua University in Beijing, under the supervision of Professor Qingxuan Zhan, a pioneer in China's architectural lighting research. At that time, funding and opportunities for international conferences were far more limited than they are today. However, Professor Zhan supported me in joining the China Illuminating Engineering Society (CIES) delegation to attend the 24th CIE Session in Warsaw, Poland, in 1999. I was likely the youngest Chinese participant at the event, and it was my first experience of traveling to Europe for an international academic conference.

A particularly memorable milestone was the 26th CIE Session held in Beijing in 2007, where I volunteered in organizing and managing the event. Since then, I have remained actively engaged with CIE and international academic events. I attended the 28th CIE Session in Manchester, UK, in 2015, as well as CIE Midterm Meetings in Hangzhou, China, and Jeju Island, South Korea.

In 2017, the Asia Lighting Conference was held in Shanghai, where I served as the conference chair. On this occasion, I specially invited Professor Yoshi Ohno, then-President of the International Commission on Illumination (CIE), to deliver a keynote speech. He encouraged me to take on a more significant role on the global stage. Following his nomination, recommendation by China Illuminating Engineering Society (CIES) and the CIE election process, I was officially elected as CIE Vice President on Publication at the 29th CIE Session in Washington, D.C., in 2019. Four years later, at the 30th CIE Session in Ljubljana, Slovenia, I was re-elected as Vice President, this time mainly responsible for education affairs—a newly established position in CIE's history. As a scholar with extensive experience in academic education, I see this role as an opportunity to leverage my expertise in academic education and professional training, strengthening CIE's global influence and contributing to its strategic development goals.

I joined the Department of Architecture at the College of Architecture and Urban Planning, Tongji University, in 2001. Tongji University, founded in 1907 by the German physician Erich Paulun with

support from both the Chinese and German governments, has a long and distinguished history. With support from renowned German lighting companies such as ERCO and OSRAM, I established China's first Architectural Lighting Laboratory at a university.

In my teaching role, I have been responsible for several undergraduate courses focusing on the Science and Art of Lighting, including Architectural Physics – Light Environment, Lighting Design, Daylight and Architecture, Science and Art in Light & Color, and the Architectural Design Graduation Project. Additionally, I have taught two graduate-level courses: Architectural and Urban Light Environment, Visual Performance and Lighting Design. In the teaching process, CIE publications are undoubtedly a professional technical reference and guide, especially for faculty and students in architecture who may not have a strong background in science programs, Physical Measurement of Light and Radiation, and theoretical concepts. These resources have significantly helped bridge the gap in foundational lighting science knowledge.

The China Illuminating Engineering Society (CIES) is China's sole national representative in CIE. Currently, I serve as Vice President of CIE and Chair of the International Exchange Committee. Over the years, I have had the privilege of engaging with several CIE Presidents, including Jack Xia (USA), Wout van Bommel (Netherlands), Franz Hengstberger (South Africa), and Warren Julian (Australia) who once served as CIE Vice President (Technical). They have all vis-

ited China multiple times and maintained close collaborations with CIES. They have also served as distinguished professors at leading Chinese universities, including Fudan University, Tianjin University, and Tongji University. Through their guidance, these international scholars have played a key role in fostering academic exchanges between China and other CIE member countries, supporting young Chinese researchers in entering the international lighting field. Through the CIE platform, I also have had the opportunity to interact with leading scholars from around the world, broadening my academic perspectives and strengthening my commitment to lighting research and education.

LED professional: What do you consider the most important skill or knowledge area for students and professionals in the lighting field today?

Prof. Dr. Luoxi Hao: The skill and knowledge requirements for professionals in the lighting industry vary depending on their professional backgrounds. Lighting is a multidisciplinary field, and globally, it is rarely offered as an independent undergraduate major. Most professionals come from related fields such as architecture, interior design, industrial design, and electrical engineering. Career paths include lighting design, electrical design, luminaire development, optical design, material, control technology, lighting education and lighting-related research in institutions.

Overall, both students and professionals should have a solid understanding of lighting science and technology, aesthetic sensibility, innovation capability, continuous learning ability, and teamwork skills.

Specific skill requirements are listed according to the career path:

Lighting and Optical Researchers:

- Comprehensive knowledge of optics and lighting principles
- Literature review competency
- Experiment and data analysis
- Technology transfer and application skills
- Awareness of research ethics
- High-level writing and creativity

Lighting Educators:

- Proficiency both in academic teaching and professional training methodology
- Curriculum design skills
- Hands-on training abilities
- Industry insight and strategy

Lighting Designers & Consultants:

- Strong optical principles
- Basic knowledge of architecture and interior design
- Creative lighting design skills
- Proficiency in software for visualization and modelling
- Project management and communication skills

Electrical Engineers in Lighting:

- In-depth knowledge of electrical systems
- Familiarity with design standards and CAD drafting
- Equipment selection and installation expertise
- Maintenance and troubleshooting skills
- Project management and safety compliance

Product Design and R&D:

- Advance optical design knowledge
- Industrial aesthetic design and structural design skills
- Circuit design and material knowledge
- Testing, validation, and innovation capabilities
- Proficiency in relevant design software
- Awareness of industry trends and project management skills

LED professional: Could you share your vision for the future of education in lighting?

Prof. Dr. Luoxi Hao: In addition to acquiring specialized scientific knowledge in the field of lighting, lighting education should place greater emphasis on developing practical skills. Students need to understand the value of research findings in practical applications, especially in areas such as LED SPD (Spectral Power Distribution) technology and smart lighting control technology. This will help students understand how to develop products that not only meet visual and performance requirements but also promote health benefits. Furthermore, it will contribute to the research and development of upstream semiconductor products and so on. With the advancement of brain-computer interface (BCI)

and wearable technologies, lighting education must also integrate these emerging technologies into research, with a particular focus on data collection and analysis methods. Students will learn how to leverage the interaction between light and the brain to develop new lighting control methods. Therefore, lighting professionals should have a comprehensive understanding of the scientific principals in this field to address a wide range of applications. The future of lighting education will be multidisciplinary, technology-driven, and application-oriented. It will continuously adapt to and integrate cutting-edge technologies to cultivate talents capable of driving future technological advancements.

LED professional: How do you see CIE's role in shaping this future?

Prof. Dr. Luoxi Hao: The International Commission on Illumination (CIE), as the authoritative organization in the field of light and lighting, can play multiple roles in future lighting education:

1. Leader in Educational Standards and Curriculum Design: Based on CIE's technical standards in colorimetry, photometry, and terminology, CIE provides educational institutions with a unified teaching framework to ensure alignment of curricula with industry needs.
2. Standardization of Knowledge Systems: CIE intends to publish professional educational guidelines to help institutions in designing courses that cover fundamental theories such as visual science, optics and applied technologies like LEDs and smart lighting. The educational content will be continuously updated to align with the latest developments in CIE knowledge.
3. Promoter of Frontier Technologies and Interdisciplinary Research: Through technical reports and research outcomes, the CIE introduces cutting-edge research findings, such as integrative lighting¹ and non-visual effects of light, into classrooms to keep students informed about emerging fields. It also fosters interdisciplinary collaboration between lighting research and disciplines like architecture, medicine, and environmental

¹CIE S 017:2020 17-29-028 integrative lighting: lighting integrating both visual and non-visual effects, and producing physiological and/or psychological benefits upon humans.

and ecology science, cultivating professionals with a multidisciplinary perspective.

4. **Bridge for International Collaboration and Resource Sharing:** CIE is trying to build a global educational network, facilitating international academic exchanges through cooperation among member countries. It supports joint research projects and student exchange programs to enhance global engagement. Additionally, by providing access to CIE's online datasets, it lowers barriers to educational resource acquisition.
5. **Connector of Industry Needs and Talent Development:** CIE is about to foster collaboration among industry, academia, and research institutions to define future skill requirements, concerning sustainable lighting and light pollution control. It encourages educational institutions to expand practical courses and develops teacher training programs to equip educators with the latest technologies and teaching methodologies.

In summary, CIE's role in lighting education will go beyond traditional academic support, positioning it as a key driver in building a global lighting educational ecosystem.

LED professional: What are the key challenges and opportunities you face as Vice President of Education (VPE) at CIE when it comes to educating the next generation of lighting professionals?

Prof. Dr. Luoxi Hao: The International Commission on Illumination (CIE), as an international academic organization, is likely not well known to most students, particularly those in my department of architecture. However, I frequently introduce them to two brilliant figures in CIE history. The first is Thomas Edison, widely regarded as the father of the electricity age. Before the 7th CIE Conference held in New York in 1928, a series of technical visits were organized, during which Edison hosted CIE delegates in his laboratory. The second is Dr. Harrison Schmitt, an American astronaut. He was the keynote speaker at the 25th CIE Conference held in San Diego in 2003. He was the one who, in December 1972, boarded the Apollo 17 spacecraft and took a picture of Earth from 45,000 kilometers away.

One of my key focuses is how to raise awareness of CIE among students, encourage them to utilize its academic resources, and stay updated on its research developments, especially the topical discussions currently being conducted by the Technical Committees (TC). Naturally, this is also my responsibility and duty as CIE Vice President of Education and a member of the Governing Board.

LED professional: How has the demand for educational programs in lighting evolved over recent years, and how has CIE adapted to these changes?

Prof. Dr. Luoxi Hao: The emergence of new technologies has significantly impacted the evolution of the knowledge system in lighting education programs. For instance, compared with traditional light sources, semiconductor lighting technology has fundamentally transformed theoretical knowledge, lighting design, and technical applications. In recent years, the advent of technologies such as the Internet of Things (IoT) and artificial intelligence (AI), combined with theoretical research on non-visual effects of lighting on health, has continuously expanded the scope and boundaries of knowledge.

CIE's technical activities are carried out through its current six divisions, covering vision and color, physical measurement of light and radiation, interior environment and lighting design, transportation and exterior applications, photobiology and photochemistry, and image technology. Under the leadership of CIE President Jennifer Veitch, CIE has focused on the United Nations Sustainable Development Goals (SDGs) and developed a research strategy aimed at supporting the achievement of 12 out of the 17 UN SDGs.

These represent some of the most pressing challenges that require solutions. CIE publications, including technical reports and notes, standards, guidelines, open access datasets, and position statements, as well as thematic seminars, tutorials and workshops on publications, help educators integrate the latest knowledge and concepts in lighting into the classroom. Undoubtedly, CIE's outputs serve as a critical resource and foundation for lighting education.

LED professional: What approaches do you find most effective for inspiring and engaging students in such a technical and specialized field?

Prof. Dr. Luoxi Hao: It is often said that passion is the best teacher! How can we motivate and attract students into the highly technical and specialized field of lighting? I would like to share some of my approaches. I have long been engaged in teaching architectural physics and light environments. Each year, I carefully design the assignment topics, ensuring they are distinct from previous years. I provide students with LED chips, guiding them through the process of wiring the electrodes, soldering heat sinks, and finally lighting up the LEDs.

Using recycled materials, they explore the relationship between light, materials, and artistic form. Our students also visit local fresh markets, analyzing different stalls such as those selling meat, vegetables, fish, and noodles, to understand the lighting requirements for fresh food, including the abstract concept of $V(\lambda)$, color rendering, color temperature, Rg, Rf and R9. Last year, we conducted a detailed comparative study of the visual systems of 20 different animals and compared them with human vision.

In another course, 'Daylight and Architecture,' students select iconic buildings from around the world and simulate how natural light interacts with specific spaces. This year, we posed an intriguing question: 'If Le Corbusier's La Chapelle de Ronchamp were built in my hometown', to inspire students from different cities to reshape the windows based on their hometown's geographical location. In our lighting design coursework, students are required to use lighting simulation software, such as DIALux, to design and calculate lighting schemes for interior spaces.

We introduce and analyze classic architectural case studies by master architects, such as Louis Kahn's Kimbell Art Museum and Tadao Ando's Church of the Light, to spark students' curiosity about how light shapes space. We also visit leading lighting companies like Signify to understand intelligent lighting control systems, integrative lighting algorithm development, and low-carbon energy-efficient LED lighting products, exposing students to cutting-edge tech-

nologies. Additionally, we invite designers or engineers to share their insights on design innovation and technical challenges in the classroom, enhancing students' professional awareness.

We have also experimented with virtual reality simulations of extreme lighting environments, such as Antarctic bases' lighting, and spacecraft cabin lighting, overcoming physical limitations and stimulating students' exploratory curiosity. For graduate students, we integrate circadian rhythm research into integrative lighting discussions, explore predictive algorithms for intelligent lighting systems, and broaden their technical horizons. Interpreting CIE technical publications to cultivate academic thinking skills is another persistent aspect of our teaching.

By breaking down complex technical content into tangible modules, we effectively overcome disciplinary barriers, fostering students' intrinsic motivation and enabling them to gain continuous feedback in the process of problem-solving.

LED professional: What recent advancements in lighting technology excite you the most, and why?

Prof. Dr. Luoxi Hao: Integrative lighting, circadian rhythm considerations, and LED spectral power distribution (SPD) technology are my primary areas of focus. I contend that lighting design and application have evolved from a purely functional focus to a deeper emphasis on the relationship between humans and space, encompassing psychological perceptions and emotional experiences. It should not only consider parameters such as luminance and uniformity but also examine the impact of light on human physiology, behaviors, and psychology. The spectral power distribution (SPD) of LEDs, as well as their color temperature and intensity or brightness, play a crucial role in shaping our perception of space. These factors can make a space feel warm or cold, relaxing or tense, thereby significantly enhancing our spatial experience. Moreover, they can also influence the levels of hormones such as melatonin and dopamine, which in turn can improve sleep quality and emotion.

Healthy lighting mimics natural light variations, such as cooler, high color temperature light in the morning to promote alertness and warmer light in the evening

to facilitate sleep. Specific wavelengths can also be helpful, such as the UV spectrum that is widely used for air purification, water treatment, and medical disinfection, etc.

The optimization of LED spectral properties and intelligent dynamic lighting can reduce night-time blue light exposure, creating a healthy lighting environment throughout the day. Meanwhile, wearable devices provide data support for measuring physiological indicators, enabling real-time optimization of lighting scenarios.

In recent years, my graduate students and I have primarily explored the application of healthy lighting in specialized scenarios, such as regulating circadian rhythms in polar day or night conditions, improving sleep and safe night-time lighting for the elderly, aiding in the treatment of postpartum depression, and optimizing the light environment in hospital wards. Additionally, tunable-spectrum lighting in medical and mental health fields enables personalized therapeutic lighting environments.

I frequently remind my students that light and illumination not only provide functional lighting for visual comfort and traffic safety but also serve as a tool for artistic ambiance, shaping space perception through light and color. Today, we harness lighting to promote human health and well-being, which is an exciting frontier that goes beyond traditional illumination.

LED professional: How do you believe lighting can contribute to solving global challenges, such as energy efficiency or climate change?

Prof. Dr. Luoxi Hao: Innovations in lighting technology play a crucial role in addressing the challenges of energy efficiency and climate change. Firstly, the widely discussed LED revolution has greatly improved energy efficiency and extended the lifespan of lighting fixtures, significantly reducing electricity consumption and the frequency of replacements. Secondly, intelligent lighting systems, equipped with sensors, timers, and photosensitive technologies, can automatically adjust brightness or switch off based on ambient light levels and human presence, minimizing unnecessary lighting. Thirdly, integrating lighting with other energy systems through the

Internet of Things (IoT) enhances overall building energy efficiency. Lastly, renewable energy sources, such as off-grid solar lighting, help reduce reliance on fossil fuels. The combination of high-efficiency LEDs with distributed renewable energy sources (e.g., wind and solar power) accelerates the transition to clean energy.

LED professional: With the rapid pace of innovation, what role do you see for CIE in helping professionals and institutions keep pace with new developments in lighting?

Prof. Dr. Luoxi Hao: The International Commission on Illumination (CIE) is the leading international authority in the field of light and lighting research. Since its founding, CIE has been dedicated to advancing lighting science and technology, including the development of lighting-related standards and guidelines, as well as the continuous improvement of calibration and measurement techniques for new light sources. The core of CIE's research is through its Research Forums. The technical committees then write the publications based on the most up-to-date research. This ensures that CIE continuously adapts to new technological advancements and application needs.

In addition to its research efforts, CIE offers educational resources and professional training to help lighting designers, engineers, researchers, and other professionals stay up to date with the latest industry developments. Through conferences, seminars, tutorials, online courses, and other educational initiatives, CIE disseminates the latest research and technological developments in the lighting field. CIE is a member of the International Science Council (ISC), which addresses global scientific and societal challenges, promoting science as a shared global resource. Additionally, CIE works extensively with the World Health Organization (WHO) on global health and well-being with a particular focus on photobiological safety, visual health lighting, non-visual effects of light, and the standardization of healthy lighting practices.

LED professional: Human-Centric Lighting is an increasingly popular topic. How do you think educational programs need to adapt to address this trend?

Prof. Dr. Luoxi Hao: CIE uses a preferred term “integrative lighting” to describe the same concept as the term “human-centric lighting” but with a wider focus. With integrative lighting, we acknowledge that light influences our behavior, physiology, health, and well-being. It affects our visual performance, visual experience and visual comfort, and has both circadian and acute effects. Integrative lighting is an interdisciplinary science that is founded upon the knowledge and technologies of various disciplines, including engineering, biology, neuroscience, psychology, and architecture. Educational programs on integrative lighting should adopt more open, diverse, and innovative approaches.

1. Establish a global interdisciplinary education network, bringing together educators from diverse academic backgrounds. This network will help learners build multidimensional and systematic knowledge frameworks, enabling them to develop a comprehensive and in-depth understanding of the complex mechanisms of integrative lighting. It will provide a strong scientific foundation and technical support for their research and practical applications.
2. Expand educational and knowledge dissemination channels. In addition to traditional lectures and publications, CIE education will provide a variety

of educational channels, including webinars and online courses delivered by CIE experts. These channels will provide comprehensive learning resources and hands-on guidance, allowing learners to access the latest research findings and real-world case studies in integrative lighting. This will promote the broader dissemination of integrative lighting theories and knowledge, facilitating the integration of research with real-world applications.

3. Develop specialized training programs focused on integrative lighting. Through these efforts, we can nurture skilled professionals and continue to energize the development of the field of human factors lighting science.
4. Leverage AI tools to explore new possibilities for integrative lighting education. CIE education is trying to enable educational resources to overcome barriers of language, geography, and discipline, making them accessible to a broader community of practitioners and enthusiasts.

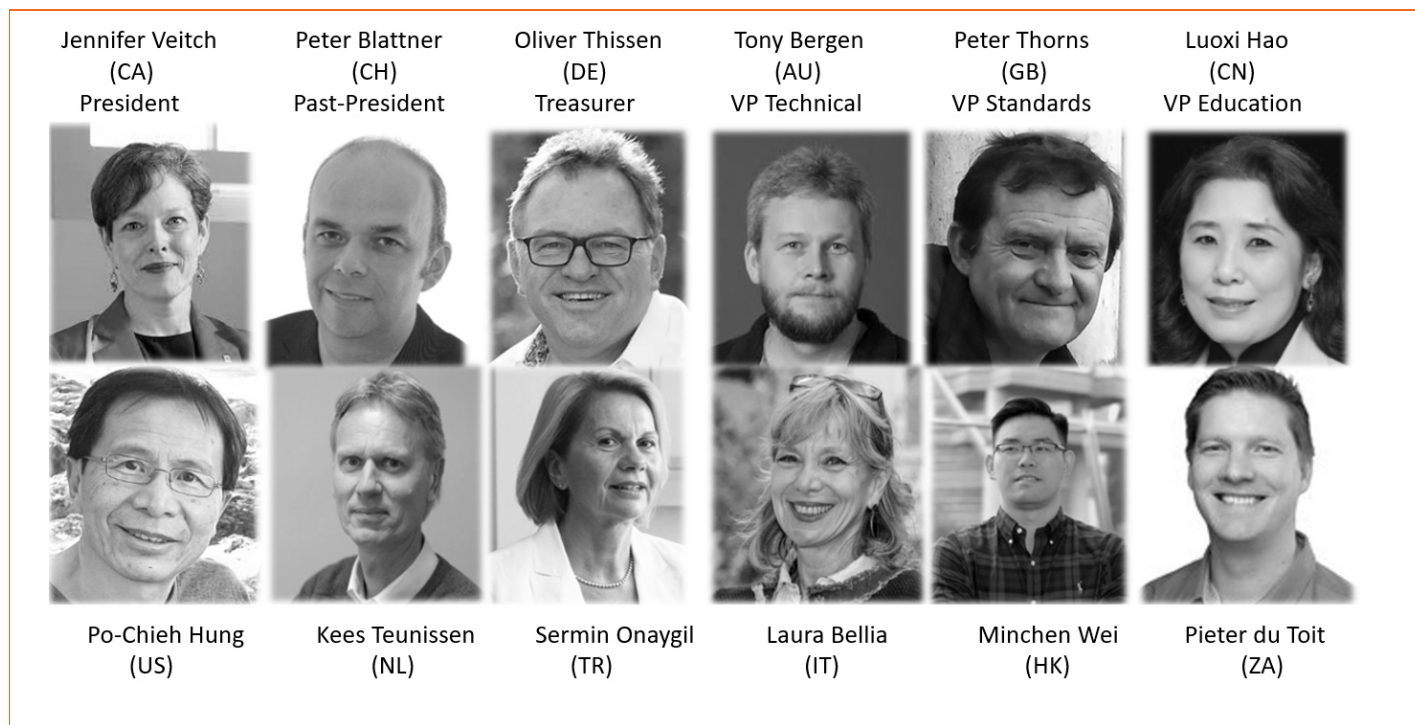
LED professional: CIE has a strong international presence. How does your role as VPE involve fostering collaboration across borders?

Prof. Dr. Luoxi Hao: CIE education will initiate global education and training programs on key topics such as healthy lighting (integrative lighting), light pol-

lution and so on. These initiatives will include online courses, workshops, and academic exchanges, providing a platform for representatives and experts from various countries to share their insights, strengthening international collaboration and fostering joint research efforts. It aims to promote and support transnational research to address critical issues such as ethnic diversity and regional variations in lighting. We encourage expert teams from different countries to collaborate on solving common challenges in the lighting field, utilizing diverse perspectives and expertise. CIE has established resource-sharing mechanisms, such as databases and publications, ensuring that experts worldwide can access and utilize the latest lighting research findings.

LED professional: What challenges do you encounter in setting international standards for education in lighting, and how do you overcome them?

Prof. Dr. Luoxi Hao: Lighting certification systems vary by country and region, offering their own distinct training and examination processes for professional qualifications that are not mutually recognized. A significant development is the European Lighting Experts Association (ELEA), which has established a harmonized European standard for lighting education, covering both indoor and outdoor lighting. Upon passing the re-



CIE Governing Board, September 2023-2027.

quired examinations, candidates can register with ELEA as European Lighting Experts (ELE) in their respective fields. Meanwhile, we are also exploring the possibility of establishing CIE-certified lighting design and professional qualifications to promote global acceptance and mutual recognition. While this concept holds great promise, it remains a highly complex undertaking and is currently only in its conceptual phase.

LED professional: Could you explain how CIE's educational initiatives contribute to a unified understanding and application of lighting standards globally?

Prof. Dr. Luoxi Hao: CIE has established a comprehensive distribution strategy for its technical standards and publications. Whenever a new standard is published, the corresponding Technical Committee (TC) is encouraged to create an instructional video, which is then made available on the CIE's official website for public access. Additionally, CIE selects key publications for inclusion in global training programs. In this context, I had the opportunity to assist the China Illuminating Engineering Society in organizing an online workshop in China focusing on CIE S 026: System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light.

To increase global accessibility, the CIE holds an annual vote to select one publication for free distribution to all member nations. Recognizing the needs of non-English-speaking countries, CIE has established a translation policy that allows national members to produce official translations of CIE publications. These translations can be sold alongside the original English editions, ensuring broader accessibility to CIE's technical resources worldwide.

LED professional: Could you tell us about a defining moment or project in your career that shaped your perspective on education in lighting?

Prof. Dr. Luoxi Hao: Over a decade ago, after completing the lighting planning and design for the 2010 Shanghai World Expo in China, I was hospitalized due to heart issues caused by overwork. During my hospital stay, I unexpectedly discovered that patient anxiety made it difficult to perform radiofrequency ablation surgery. Together with my graduate

students, I explored the idea of installing colored lights and media interface above the operating table to help alleviate patients' anxiety during surgery. Evidence-based experiments confirmed that this approach was significantly more effective than verbal reassurance from doctors. This discovery made me deeply aware of the immense potential of healthy lighting innovation.

Since then, I have led my team in researching and applying healthy lighting in various environments, including hospitals, elderly care facilities, polar regions, classrooms, and offices, etc. Our work has received support from national funds, as well as awards from the Ministry of Science and Technology and the Ministry of Education of China. We have adopted a problem-driven approach, using evidence-based research to enhance sleep rhythms, emotions, and cognitive abilities of different groups through lighting. This evidence-based methodology has shaped our research model in recent years. Additionally, I have been invited to various conferences and forums to present the multi-dimensional health effects of light on vision, physiology, and psychology, introduce our innovative achievements, and educate the public about light and health. My goal is to fully harness the therapeutic benefits of light and contribute to public health and well-being.

LED professional: What do you see as the most rewarding aspect of your role as VPE at CIE?

Prof. Dr. Luoxi Hao: As the newly appointed Vice President of Education (VPE) at CIE, a pioneering role within the organization, I am at the beginning of an exciting journey. In my previous term, I was responsible for publications, but now my focus has changed to leading educational affairs. At recent CIE quadrennial conferences and within Technical Committee working groups, I've noticed an increasing trend: university professors are seeking CIE-sponsored activities and projects that support both their professional development and their students' academic growth. This aligns with CIE's commitment to education.

With the support and encouragement of current the president, Jennifer Veitch, and former president Peter Blattner, I have begun collaborating with members of the Standing Panel on Education

(SPE) to develop CIE's educational initiatives. Beyond traditional educational efforts, we recognize the CIE platform's potential to facilitate extensive academic exchange and international cooperation. This vision has led to the creation of the CIE Global Education Community.

Being part of the CIE leadership team is more than a professional commitment—it's a unique opportunity to build a global educational resource-sharing platform that promotes cross-cultural collaboration and expands international exchange opportunities for educators and students worldwide. Becoming part of the CIE management team and creating a platform for sharing global educational resources, fostering cross-cultural educational collaboration, and offering more international exchange opportunities to teachers and students globally is both a professional responsibility and a career aspiration that I am truly proud of. Seeing educators from diverse backgrounds come together to advance our shared goals is incredibly rewarding.

LED professional: As someone at the forefront of lighting education, how do you personally stay informed and inspired in such a fast-evolving field?

Prof. Dr. Luoxi Hao: That's a great question! In my view, teaching is a noble profession centered on sharing knowledge and educating students. In today's era of information explosion and the astonishingly rapid integration of artificial intelligence (AI) into our lives, constructing a personal knowledge framework and cultivating the habit of continuous learning are fundamental qualities for educators—especially in a rapidly evolving field like lighting technology. I constantly remind myself that staying updated is as natural and essential as eating and drinking. To achieve this, I keep reviewing academic literature, following industry news, exploring the latest design cases, attending academic conferences, and engaging in discussions with experts from various fields. This allows me to stay informed about the latest advancements and trends in lighting, optics, architecture, design, AI, and medicine. Maintaining an open and innovative mindset is crucial, as is the courage to experiment with new methods and technologies in lighting and design. Practical engineering projects often provide insights by addressing the diverse lighting needs of different people

and spaces, sparking new ways of thinking. Over the past years, I have actively explored interdisciplinary collaboration at the intersection of medicine and engineering, integrating knowledge and techniques from multiple fields. I have even expanded my scope beyond the traditional field of lighting.

LED professional: What do you hope to accomplish as VPE at CIE in the coming years? Are there any specific goals or milestones you are particularly passionate about?

Prof. Dr. Luoxi Hao: As a professor engaged in lighting education, I deeply understand the importance of talent development. The undergraduate and graduate students currently being educated, represent the future of the lighting industry. Recognizing this, CIE has established a Standing Panel on Education (SPE), dedicated to advancing global knowledge and expertise in light and lighting across academic, professional, and public domains. By leveraging international joint research, publications, and expert networks, our panel aims to facilitate knowledge exchange, promote inclusive education, and foster innovation. Through diverse educational initiatives and collaborative efforts, the panel seeks to support the development of lighting professionals at all career stages, from students to experienced experts. The panel aims to build a global lighting community, advancing the field through education, collaboration, and talent development.

CIE's Educational efforts are divided into two key areas: academic education and professional education. Academic education aims to provide rigorous and scientifically grounded training for students, researchers, and academics in the field of light and lighting.

Professional education focuses on offering practical, industry-relevant, and up-to-date knowledge to professionals, enhancing their skills to meet the evolving demands of the lighting industry.

To launch these initiatives, SPE has developed a survey to collect feedback from experts, scholars, and students on CIE educational activities. We seek insights into:

1. The types of activities and programs

- that should be developed on the CIE platform.
2. How CIE resources can be leveraged for continuing education, training, and professional certification.
3. Future directions and recommendations in alignment with the CIE Research Strategy 2023-2027.

After multiple discussions, the SPE (Standing Panel on Education) has outlined the scope, vision, and mission of both academic and professional education. We have proposed feasible action plans, including educational initiatives, early-career professional development programs, competitions and awards.

CIE houses an extensive range of educational resources. As a global authority in light and lighting research, CIE offers a vast collection of publications, a cutting-edge knowledge base, and a network of leading international experts. The CIE website will soon launch a dedicated education section, offering relevant content and strategic initiatives. Our strategies include organizing student-centric activities, encouraging interdisciplinary research – especially projects that reflect cultural diversity – providing platforms for researchers to find collaborators.

We also actively encourage CIE National Committees to initiate education-related activities, such as forums, training sessions, workshops, a potential global thematic series, such as Europe-Asia Dialogue: From Light to Human, international student competitions, site visits to outstanding lighting projects, and academic exchange programs.

Over the next few years, SPE will focus on the following key questions:

1. How can our educational activities enhance CIE's value and impact, particularly in alignment with its research strategy?
2. How can advancements in lighting education support CIE, its divisions, and technical committees?
3. What resources and support can CIE provide to expand and strengthen global lighting education?
4. Among our initial action plans, which key activities should be prioritized to effectively advance CIE's educational mission?

SPE's ultimate goal is to enhance CIE's global influence and attract more schol-

ars, especially early-career researchers, to join CIE. We encourage their active involvement in CIE technical committees (TCs), ensuring that students and young scholars gain access to cutting-edge knowledge at the early stage of their careers. This participation will position them as key contributors to the dissemination of CIE's research outcomes.

Additionally, we advocate for technological collaboration, including industry-academia-research partnerships to drive innovation. Our vision is to establish CIE as a leading platform for lifelong learning, professional development, and knowledge exchange in the lighting field.

We encourage students from around the world to present their research papers at the CIE conference. We'd also like to inform you that the CIE Midterm Meeting will be held in Vienna, Austria, from July 4-11, 2025. Additionally, I will be hosting an education workshop where three renowned experts will share their valuable insights and experiences in lighting education. I'm also pleased to share information about another major CIE event – the 31st Quadrennial Session of the CIE, which will take place in Nanjing, China, in 2027. We warmly invite all of you to join us and experience the rich culture of China!

Our motto is: From Learning to Leading, Growing with CIE!

LED professional: How do you see artificial intelligence or other emerging technologies influencing education and standards in lighting?

Prof. Dr. Luoxi Hao: Artificial intelligence introduces new tools and methods for lighting education, such as an AI-driven virtual simulation platform and a remote experiment platform. Artificial intelligence enhances the personalization and interactivity of educational models, and this applies to all disciplines. Traditional lighting standards consist of static metrics, with everyone following a single index. Artificial intelligence is driving the evolution of lighting standards towards dynamic and adaptive models, as each application scenario has multiple objectives rather than a single one. Additionally, individual differences in eye physiology, visual characteristics, and cognitive abilities of individuals further necessitate an adaptive approach to lighting.

LED professional: If you could give one piece of advice to students entering the field of lighting, what would it be?

Prof. Dr. Luoxi Hao: To young professionals embarking on a career in the lighting industry, my advice is to focus on establishing a strong knowledge base, staying updated with the latest technological developments, fostering an interdisciplinary mindset, and embracing lifelong learning. The most crucial aspect is to develop a deep understanding of how light influences human perception, emotions, and well-being. With dedication and curiosity, you can evolve into a highly skilled and impactful professional, making meaningful contributions to this ever-evolving field.

LED professional: Based on your professional experience in architecture and your focus on illuminated spaces and design, what are your insights regarding human factors and health lighting?

Prof. Dr. Luoxi Hao: Human factors and health lighting have become prominent research areas in recent years. Over the past few years, my research has primarily focused on "environmental healing and proactive light-based health interventions." By integrating medical and engineering methodologies and conducting evidence-based experiments, I have worked on developing intelligent healthy lighting technologies to mitigate environmental stressors. Specifically, my research explores therapeutic lighting and intelligent human-centric health support systems tailored to diverse environments and populations. These include Antarctic healing cabins, hospitals, homes, and schools, targeting individuals exposed to extreme day-night conditions, vision-deprived Antarctic expedition members, patients, the elderly, postpartum women, and children.

Another significant aspect of my work has been the systematic quantification of light pollution in Shanghai and its impact on livability. I have proposed standardized parameters and threshold values for ecologically sustainable urban lighting for the Shanghai Municipal Government, providing scientific support for regulatory updates and management guidelines of Shanghai urban lighting.

Based on my nearly two decades of research, design, and engineering practice, I have published a monograph titled "Light and Health." Overall, in architectural design, well-executed integrative lighting can enhance spatial efficiency and workplace productivity, improve comfort and well-being, and have a positive physiological and psychological impact on visual, sleep, and emotional health.

However, health lighting requires the precise calibration of lighting parameters—including intensity, spectrum, and light distribution—tailored to different age groups, regional light climate variations, and the unique needs of populations with specific health conditions. This approach enables the creation of finely tuned lighting scenarios.

Key challenges in the field include tracking individual light exposure over time, advancing wearable devices, quantifying biological effects, and addressing ethics considerations in experiential studies. There is still progress to be made in integrative lighting and health research. In the future, lighting design will likely evolve beyond the domain of designers alone. Instead, it will require a multidisciplinary approach, integrating expertise from medicine, biology, and data science.

LED professional: Thank you so much for this exclusive and extensive interview about you, your profession and about CIE². It was a pleasure talking with you.

Prof. Dr. Luoxi Hao: Thank you very much. It was also a pleasure talking with you. ■

For additional information, please visit <https://cie.co.at>.

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²Additional CIE interviews published in LED professional Review (LpR) include: Dr. Jennifer Veitch (LpR#103), Peter Thorns (LpR#104), and Tony Bergen (LpR#105).



International Commission on Illumination
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JOIN US FOR CIE 2025 MIDTERM MEETING

VIENNA, AUSTRIA
July 4-11, 2025

The International Commission on Illumination (CIE) invites you to the **CIE 2025 Midterm Meeting**, taking place from **July 4-11, 2025**. The meeting features the biennial **CIE Scientific Conference**, which will be followed by the **CIE Divisions and Technical Committee (TC) meetings** where CIE's ongoing work will be discussed.

Key Events

- **CIE Scientific Conference** | July 7–9, 2025
- **Welcome Reception at Vienna City Hall** | July 6, 2025
- **CIE Divisions & TC Meetings** | July 10–11, 2025

Registration Now Open: Secure your spot at the CIE 2025 Scientific Conference.
Early bird registration available until May 1, 2025.



CIE2025 WEBSITE

Key Highlights

- **Keynote Lectures** featuring topics on AI in the colour industry, light pollution, and light & human health
- **Workshops** exploring topics such as indoor lighting, colour management, HDR imaging, road lighting, light & insects, and lighting education
- **Two Days of Poster Sessions** presenting innovative research and new ideas
- **Three Parallel Sessions** showcasing research across all six CIE Divisions
- **Networking Events** for students and early-career professionals with CIE Leadership
- **On-Site Exhibitions** highlighting the latest in lighting science and technology
- **Social Events:** Sightseeing tour, CIE Badminton Tournament, Gala Dinner

We look forward to welcoming you to Vienna for what promises to be an inspiring and insightful event!

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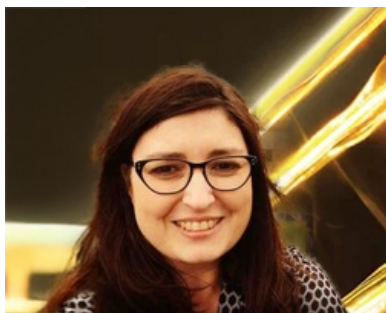
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Your Future is Bright at LightFair: The Ultimate Lighting Event You Can't Miss!

LightFair 2025 | May 4-8, 2025 | Las Vegas, NV

The lighting world is about to shine brighter than ever at LightFair 2025, the premier event uniting the global lighting community. Scheduled to take place in the entertainment capital, Las Vegas. This industry-defining tradeshow and conference will illuminate the latest innovations, create unparalleled networking opportunities, and deliver an educational program that sets the standard for excellence. Whether you're a lighting designer, architect, specifier, distributor, manufacturer, or any other professional in the lighting industry – LightFair 2025 is your must-attend event.



“LightFair is where the best minds in lighting come together to learn, collaborate, and innovate.”

KRISTY MEADE, VICE PRESIDENT, TECHNICAL SHOWS, MESSE FRANKFURT INC.



For more information visit
lightfair.us.messefrankfurt.com

Experience a World-Class Educational Program

Education is at the core of LightFair 2025, curated by Brienne Willcock, IES Director of Education & Standards, and a team of well-respected thought-leaders from the IES and IALD, this year's conference program is set to exceed all expectations. Featuring an elite lineup of industry leaders, educators, and technical experts, attendees will have access to deep-dive sessions, workshops, and forward-thinking panel discussions covering all facets of lighting technology, design, and application. From sustainability and smart lighting controls to human-centric lighting and emerging design trends, LightFair 2025 will deliver cutting-edge knowledge to empower attendees in their careers.

“Our goal is to provide attendees with the most comprehensive and impactful educational experience in the industry,” says Kristy Meade, Vice President, Technical Shows, Messe Frankfurt Inc. “We are curating sessions that not only address current challenges but also anticipate the needs of the future. LightFair is where the best minds in lighting come together to learn, collaborate, and innovate.”

The conference will be structured into specialized learning tracks, ensuring that professionals across all sectors can tailor their experience to their unique interests. Attendees can expect accredited courses offering valuable CEUs through expert-led presentations that bring concepts to life.

Discover the Industry's Leading Manufacturers

The LightFair 2025 exhibit hall will be a hub of innovation, showcasing an impressive roster of top lighting manufacturers. Attendees

will have the opportunity to explore groundbreaking product launches, test the latest in LED technology, and engage directly with representatives from the most influential brands in the industry.

From major global players to dynamic up-and-coming brands, the show floor will feature solutions for architectural lighting, residential applications, commercial spaces, outdoor environments, and beyond. This is the place to experience firsthand the materials, designs, and technologies driving the future of lighting. Whether you're sourcing for a new project, comparing solutions, or seeking inspiration, LightFair 2025 will provide access to the best the industry has to offer.

Step Into Immersive Lighting Installations

Prepare to be amazed by LightFair 2025's immersive lighting installations, designed to showcase cutting-edge applications in real-world environments. These stunning exhibits will highlight the latest advancements in dynamic lighting, color tuning, and interactive experiences. Step into breathtaking visual environments that demonstrate the power of light to transform spaces, evoke emotions, and enhance functionality.

Each installation will be a collaboration between top designers, lighting manufacturers, and technology innovators, creating an unforgettable experience that bridges art and technology. Attendees will leave inspired with new ideas for integrating advanced lighting solutions into their projects. From biophilic design and wellness-focused illumination to the latest developments in color rendering and sustainability, this area will be a curated showcase of emerging concepts.



Explore the All-New Trends Area

LightFair 2025 introduces Trends at LightFair, a dedicated space, expertly curated by renowned lighting designers Steven Rosen and Anne Kustner, where attendees can explore the most influential movements guiding the future of lighting and be inspired to push the boundaries of creativity.

Interactive displays, expert-led talks, and trend-focused product exhibits will provide invaluable insights for professionals looking to stay ahead of the curve. Whether you're designing for residential, commercial, or urban spaces, the Trends Area will serve as an essential resource for future-forward lighting inspiration.

Dive Into Innovation at the Technology Pavilion

Technology is at the forefront of the lighting industry's evolution, and LightFair 2025's Technology Pavilion will put the spotlight on the most advanced solutions available today. This dynamic space will feature developments in smart lighting, IoT integrations, AI-driven controls, and energy-efficient solutions.

Attendees can engage with live demonstrations and get hands-on with the latest software and hardware driving the industry forward. From intelligent lighting systems, energy management solutions, or the next generation of connectivity, the Technology Pavilion will provide a deep dive into the innovations of tomorrow's lighting landscape.

Unleash Creativity at The Designery

For those who live and breathe lighting design, The Designery will be a must-visit destination within LightFair 2025. Another stage for examining the impact of lighting, The Designery will be a space of inspiration and creativity. Featuring expert driven discussions with leading designers and presenters, this area will highlight the challenges, changes, solutions and trends facing the lighting industry. Lighting professionals will have the chance to discover new approaches to layering light, integrating smart controls, and harnessing the power of lighting to enhance mood and functionality in residential and commercial spaces. Stop by this stage if you're looking to refine your design approach, seeking success stories, new techniques, or simply want to join in the conversation – The Designery will be your go-to destination for creativity and innovation.

Connect & Celebrate at the Opening Night Reception

Networking takes center stage at LightFair 2025, and there's no better way to kick off the event than the highly anticipated Opening Night Reception at Brooklyn Bowl. This exclusive gathering will bring together industry professionals in a lively, energetic setting, offering the perfect opportunity to build connections, exchange ideas, and celebrate the lighting community.

With live music, food, drinks and a vibrant atmosphere, the Opening Night Reception promises to be a highlight of the

event. Start reconnecting with colleagues or meeting new industry contacts, this evening of celebration will set the tone for an unforgettable LightFair experience.

LightFair 2025: Your Must-Attend Lighting Event

With its world-class educational program, leading exhibitors, immersive installations, and exciting networking events, LightFair 2025 is the ultimate gathering for lighting professionals. This is your chance to engage with the industry's brightest minds, explore groundbreaking innovations, and gain the insights needed to stay ahead in a rapidly evolving field.

Don't miss your opportunity to be part of the lighting event of the year. Mark your calendar for LightFair 2025, May 4 – 8, and join us in Las Vegas for an experience that will shape the future of lighting. ■

REGISTRATION

Register today and get ready to illuminate your future!



Enterprise Health: The Hidden Key to Lighting Industry Success

Wojtek Cieplik, Founder of LightGrow Consulting and Partner at Brandt & Partners

Key Insights

- Inefficiencies cost lighting manufacturers an estimated \$3.5 billion annually, often undetected by traditional KPIs [1].
- The Enterprise Health Program uncovers these hidden inefficiencies and transforms them into competitive advantages.
- Measure your gaps now - scan a QR code for a quick call and start solving inefficiencies today.

This article, tailored for LED professional Review's 45,000 industry professionals, explores why organizational health is a vital yet neglected driver of success, how inefficiencies silently erode innovation and profitability, and how the Enterprise Health Program (EHP) offers an end-to-end solution that transcends traditional performance tracking. Drawing on industry-specific diagnostics and proven transformation strategies, EHP positions lighting firms to thrive in an era of unrelenting change.

The lighting industry is at a pivotal juncture, facing rapid transformations driven by regulatory pressures, technological advancements, and intensified global competition. From the European Union's stringent Single Lighting Regulation (SLR) to the rise of smart lighting and IoT integration, manufacturers are under unprecedented pressure to innovate, comply and compete. Yet, amid this external complexity, a critical internal factor often goes overlooked: organizational health.

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Industry Context and Challenges

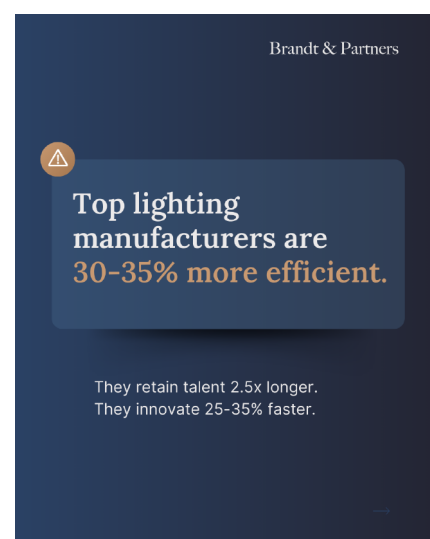
The lighting sector is navigating a "perfect storm" of regulatory tsunamis and sustainability imperatives. Key regulatory shifts include:

- The European Union's Single Lighting Regulation (SLR) and Energy Labelling Regulation (ELR), effective since December 2019, which redefine energy efficiency and labeling for light sources.
- The US and UK's proposed 125 lm/W minimum energy performance standard by 2028 further intensifies this pressure, prioritizing blue-pump LEDs for efficiency. Critics warn this focus overlooks health costs such as sleep disruption and chronic disease risks from blue-rich light at night, potentially sidelining circadian-friendly solutions, highlighting the need for regulations that integrate broader scientific insights and inclusive communication to address these emerging imperatives.
- India's mandatory star labeling for LED lamps, aligning with global energy efficiency pushes [2].

These regulations, alongside sustainability imperatives like circular economy, carbon-reduction standards, Ecodesign, and re-manufacturing, place unprecedented pressure on manufacturers. Technological innovation is another driver, with LED adoption - now 20 years mature - smart lighting, and IoT integration transforming the industry [3]. Yet, challenges persist beyond efficiency: managing light controls and protocols, mitigating flicker, optimizing spectra for vision, emotion, and human circadian health, and addressing post-EOL sustainability further test manufacturers' agility [4]. For instance, smart lighting systems were projected to soar in popularity in 2024, enabling remote control and energy optimization. Digital transformation, AI impact, and supply chain pressures further com-

plicated the landscape, with competition from Far East manufacturers now offering higher-quality products, eroding traditional cost advantages.

Given these tectonic shifts, efficiency, agility, and talent retention are more critical than ever. PwC's 27th Annual Global CEO Survey, highlights the urgency, with 45% of 4,700 CEOs uncertain about their company's survival over the next decade if they remain on their current path, and 78% convinced digital transformation will fundamentally alter value creation [5].



Organizational Health: The Key to Thrive

Organizational health, defined as the effectiveness of internal communication, leadership alignment, and culture, is the backbone of business resilience, innovation, and growth in any industry. Inefficiencies such as talent turnover (churn), leadership misalignment, and sluggish decision-making can cost millions but often remain hidden until financial reports reveal damage. For example, manufacturing inefficiencies can lead to increased labor costs and waste, with the automotive sector losing \$22,000

per minute of downtime [6]. In lighting, similar issues can hinder innovation, hurt margins, and create risks, especially under regulatory and technological pressures.

Publicly available statistics reveal that 67% of lighting companies miss critical efficiency, with manufacturers losing an estimated \$3.5 billion annually due to inefficient processes, top performers achieving up to 35% more efficiency, and a 5% efficiency boost potentially saving millions [7]. Traditional KPIs show outcomes, not causes, leaving firms blind to inefficiencies until it's too late. Organizations fixated on short-term results often prioritize immediate cost-cutting over investments in process optimization and infrastructure, perpetuating inefficiencies and degrading internal communication, which fosters confusion and weakens cohesion. Companies must turn to deeper diagnostics and transformation to uncover these hidden inefficiencies and turn them into performance drivers. These challenges play out in ways many recognize—here's where a new solution steps in.



Efficiency isn't just about financials or operations - it's about people.

Use Cases: Where Challenges Meet Solutions

Common inefficiencies hide behind everyday scenarios. A new program, the Enterprise Health Program, can step in to address them:

- *Meeting targets but stuck?* A 500-employee lighting manufacturer can uncover communication and workflow gaps, boosting efficiency by up to 10%.
- *KPIs dropping, cause unclear?* A tech firm with rising turnover can reveal disengagement, restoring performance through better alignment.
- *Evaluating an M&A project?* A private equity firm can identify post-merger risks and leadership gaps, sharpening its strategy.
- *Struggling post-merger?* A large lighting component enterprise can ease friction and silos, speeding integration.

- *Facing a leadership shift?* A mid-sized firm can stabilize operations during a CEO change with practical support of such team assessments, talent optimization through psychometric analysis.

These examples flag gaps traditional tools miss - a gap this program is designed to close.

Current Diagnostics and Their Limitations

Companies often turn to familiar methods to measure efficiency, but each falls short:

- **Employee satisfaction surveys:** These can overestimate engagement, especially if run internally - employees may not answer honestly. HR-designed surveys often skew positive, masking true issues like poor motivation or misaligned roles
- **Key performance indicators (KPIs):** Metrics like costs or conversion rates show symptoms, not causes. Low lead conversion might stem from a job misfit or lack of purpose - like placing a high-energy FMCG sales rep in a specifier sales role, where success depends on education, brand lobbying and long-term relationship-building rather than rapid transactions and negotiations. Rising recruitment costs could signal slow, overcomplicated processes driving candidate drop-offs, not just hiring challenges. Cash flow hiccups might reflect misaligned priorities ('are we after margins or revenue?'), not just late payments. These blind spots demand a deeper look.
- **Lean and Six Sigma:** These optimize processes but fail to address organizational self-deception, talent engagement, or cross-functional collaboration, missing broader cultural and leadership challenges. They focus on operational efficiency without considering people or mindsets.
- **Leadership reviews:** Useful for individual

critiques, they skip systemic flaws, leaving broader inefficiencies untouched.

These tools, though valuable, can't keep pace with the lighting industry's rapid shifts - agility, innovation, and resilient teams need more. They overlook hidden drags like low motivation or strategic blind spots, gaps a new approach like the Enterprise Health Program is built to close.

Introducing the Enterprise Health Program

The Enterprise Health Program is not generic consulting; it's a tailored, industry-specific solution for lighting firms, focusing on both diagnosis and transformation. It stands apart from traditional methods by:

- Being data-driven yet human-centric, balancing quantitative analysis with qualitative insights.
- Going beyond measurement to actionable change.
- Targeting sector challenges like regulations, tech shifts, and competition.

Backed by psychological research validated on a sample of 1,600 respondents and registered as an EU innovation, the Enterprise Health Program ensures credibility and effectiveness [8]. It targets mid-sized organizations (200-5,000 employees), uncovering inefficiencies that drain value.

The program begins with a structured engagement process, inviting firms to explore their efficiency gaps through accessible, complimentary steps, including the self-assessment Enterprise Health Survey, before committing to its core diagnostic and transformation phases, as outlined in **Table 1**.

The initial three steps - offered at no cost - lay the groundwork for the Enterprise Health Audit (EHA) and Enterprise Health Transformation (EHT), ensuring a customized approach from the outset.

Step	Description	Duration
Pre-Survey Interview	A video call exploring your views on organizational efficiency, capturing company and industry context.	30 min
Enterprise Health Survey (EHS)	A complimentary online questionnaire probing challenges across all diagnostic areas.	10 min
EHS Report	A tailored report with insights and recommendations, scope proposal for the EHA (next step), delivered via video call.	60 min
Enterprise Health Audit (EHA)	Comprehensive and precise diagnosis of inefficiencies, backed by data-driven insights.	4-6 weeks
Enterprise Health Transformation (EHT)	Structured transformation delivering measurable improvements - innovation, efficiency, alignment.	3-12 months

Table 1: The Enterprise Health Program begins with a structured engagement process.

Components of the Enterprise Health Program: Enterprise Health Audit

The Enterprise Health Program's diagnostic core, the Enterprise Health Audit (EHA), examines organizational health across six key performance areas with scientific precision:

1. *Greatness Diagnosis:*

- It examines how well the organization operates in line with high-performing companies, based on international research. It compares the company against 36 areas across individual potential, teamwork, and organizational impact, identifying deviations as opportunities for improvement.
- The Greatness Diagnosis assesses an organization's ability to execute its strategy effectively. It evaluates the clarity and alignment of strategic objectives, the robustness of KPIs and supporting processes, and the organization's capacity to translate vision into action. Additionally, it measures how well employees understand and engage with the strategy, ensuring alignment across all levels of the company.
- Only 10-15% of companies achieve and maintain enterprise greatness at 80% or higher, making this diagnosis critical for identifying and closing the gap to excellence.
- For lighting companies, this could assess how well a company aligns with best practices in LED innovation or smart lighting adoption, ensuring it grows up to four times faster by approaching excellence.

2. *Engagement & Retention Diagnosis:*

- Goes beyond traditional satisfaction surveys by analyzing both intrinsic and extrinsic motivators that drive employee commitment, performance, and retention [9].

- Intrinsic motivators (based on Thomas' research on work engagement) include meaningfulness (commitment to purpose), choice (freedom in actions), competence (skill alignment), and progress (goal achievement).
- Extrinsic motivators (per Gallup's global engagement research in 140 countries) include material factors (work environment, remuneration, development opportunities) and non-material factors (leadership inspiration, team dynamics, company culture) [10].
- The EHA assesses leadership impact, organizational culture, and motivation gaps across different levels, generations, and tenure groups. These gaps often manifest as increased overtime, turnover (churn) and absenteeism - draining profits and weakening competitive strength.
- For lighting firms, maintaining a highly engaged workforce is critical for driving innovation under regulatory pressures and AI / digital disruption.

3. *Human Negative Self-Interest Diagnosis (Organizational Self-Deception):*

- Addresses a little-known problem where self-deception distorts reality, becoming a barrier to performance. It assesses attitudes and mindsets, as behaviors determine results, and mindset determines behavior, based on decades of human research.
- Identifies wasted negative energy spent on blame, internal conflicts, and lack of accountability, asking how this can be redirected to achieve organizational goals. For lighting companies, this could reveal overestimations in innovation readiness, impacting strategic decisions like smart lighting investments.

4. *Psychosocial Measurement (ESG Recommendation):*

- Based on recommendations from the International Labour Organization (ILO) and EU-OSHA, this assesses workplace risks like stress, workload, and organizational culture, linking to ESG (Environmental, Social, Governance) for sustainability [11,12].
- Covers work environment, workload, autonomy, management support, workplace relations, and stress coping strategies, ensuring compliance with legal requirements for annual risk assessments.
- Companies with strongly aligned cultures achieve 25-35% higher productivity, a gap the Program helps close through targeted interventions. For lighting firms, it aligns culture with sustainability goals like circular economy, enhancing market positions.

5. *Time Management Diagnosis:*

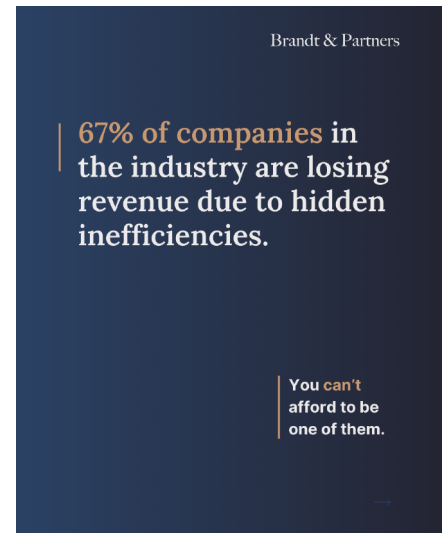
- Analyzes effectiveness along four components: goals (specificity, communication), priorities (alignment across levels), time management conditions (tools, processes), and "time robbers" (decision-making, deadlines, cooperation).
- Optimizes workflows, minimizes waste, prevents stress, and enables quick responses to market changes, crucial for lighting firms facing rapid technological shifts. For example, efficient time management can reduce production delays in LED manufacturing.

6. *Organizational Survey (Customizable Diagnostics):*

- Tailored to client priorities, this allows for deep dives into specific areas, ensuring relevance to lighting sector challenges e.g. adapting to smart building requirements or regulatory compliance. It leverages respondent subjectivity for precise conclusions, enhancing intervention effectiveness.



Enterprise Health Program (EHP) targets mid-sized lighting companies (200-5,000 employees). Its core, the Enterprise Health Audit (EHA), takes 4-6 weeks.



The Enterprise Health Audit follows a structured process with defined phases, as shown in **Table 2**:

The Audit is conducted through an anonymous psychometric survey - a focused questionnaire that takes approximately 20 minutes for an individual to complete. This ensures candid, actionable insights while respecting employee privacy.

The Audit's advanced data drill-down capabilities allow for analysis by unit and time, enabling firms to pinpoint inefficiencies with precision. High-resolution reporting segments insights by organizational level, business unit, generation, service length and gender, ensuring tailored interventions. Validated on a representative sample of 1,600 people, EHA meets rigorous reliability standards, making erroneous results virtually impossible. Benchmarking against group, industry, and territorial data further sharpens strategic decision-making. Multilingual support accommodates foreign legal entities, and execution is flexible via phone, laptop, paper-based, or corporate terminal. The Enterprise Health Audit adheres to GDPR standards with advanced encryption for data analysis and storage, and transparent practices for data usage and communication, ensuring organizational data protection.

The most transformative insights come from unexpected connections – usually not just from one dataset, but across multiple, seemingly unrelated sources. EHA's strength lies in synthesizing data from six areas to reveal hidden issues traditional tools overlook.

The Enterprise Health Audit's comprehensive approach can address underlying issues affecting key performance metrics across departments, as shown in **Table 3**.

Components of the Program: Enterprise Health Transformation

The Enterprise Health Transformation is a 3-12-month collaboration. Immediately after completing the Enterprise Health Audit, the customer begins transforming performance areas identified as 'red' (critical) or 'yellow' (problematic). It deploys targeted measures that focus precisely on the most critical needs. The Transformation can be a concise phase, offering a strategic roadmap and implementation support for 2-3 key performance areas, or it can provide comprehensive strategic execution support, addressing all critical and problematic areas through focused coaching, mentoring, and strategic workshops. Moreover, for lighting firms, it may include tailored services such as an IoT

Phases	Content	Caretaker	Duration
Calibration	Scope: size, sample, units, levels, all 6 or selected performance areas	Head of HR, CEO	1 day
Execution	Distributing secure surveys (email or paper)	Workforce	2-4 weeks
Evaluation	Detailed reports by departments and levels (further drill-down possible)	-	30 min
Reporting	Presentation of tailored results	CEO	1 day

Table 2: The Enterprise Health Audit follows a structured process with defined phases.

Department	Metric	Potential Underlying Problem Addressed by EHA
Finance	Return on Investment (ROI)	Human Negative Self-Interest Diagnosis could identify decision-making biases affecting investment choices
Sales	Lead Conversion Rate	Engagement & Retention Diagnosis might uncover motivation issues impacting sales performance
Marketing	Return on Marketing Investment (ROMI)	Greatness Diagnosis could identify misalignment between marketing strategies and organizational goals
Logistics	On-Time Delivery Rate	Human Negative Self-Interest Diagnosis might reveal communication barriers affecting timely deliveries
Quality	Customer Satisfaction Score	Engagement & Retention Diagnosis might reveal employee satisfaction issues affecting product quality

Table 3: The Enterprise Health Audit's comprehensive approach can address underlying issues affecting key performance metrics across departments.

and smart technology assessment and integration plan, an evaluation of sales and specification channels, or support for procurement, quality optimization or supply chain resilience drawn from Brandt & Partners' cross-industrial expertise.

The Enterprise Health Transformation is tailored for lighting companies, reflecting their fast product cycles, supply chain complexity, and engineering-driven cultures. Its key measures include:

- Roadmaps, action plans and regular support: Monthly status checks for D-level leaders ensure that progress stays on course with real-time adjustments, while quarterly mentoring sessions for C-level executives refine strategic direction e.g., prioritizing IoT integration or regulatory compliance - to sustain long-term impact.
- Strategic workshops: These provide strategic alignment for C- and D-level leaders and deliver support for department heads using detailed Enterprise Health Audit reports.
- Leadership coaching: Offered in two modes 'Enhance Performance' or 'First 100 Days', the coaching empowers executives to discover their authentic leadership style, align with organizational

goals, and lead with impact in a fast-evolving lighting sector.

- Team & individual assessments: These involve deep dives into critical departments.
- Talent optimization & job-fit assessment: This includes psychometric analysis of a person's thinking, behavior patterns, and interests. The in-depth evaluation of individuals adds a robust layer of data-driven analysis to critical performance areas. It can be conducted for leaders of all hierarchies or extended to their teams.
- 12-Month reporting & benchmarking: This repeats the Enterprise Health Audit to track progress and compare against industry peers, incorporating additional geographical and sector-specific deep dives.

The Enterprise Health Transformation is scalable and modular, beginning with high-impact improvements and advancing to long-term transformation, ensuring growth, resilience, and sustained efficiency gains. Clients select from these measures based on their Enterprise Health Audit findings and strategic priorities, tailoring the scope to their specific needs - whether a focused intervention or a full strategic overhaul.

Case Studies: Program in Action

The Enterprise Health Program delivers tangible results by uncovering hidden inefficiencies and driving transformation across lighting firms. The following case studies - Lumina Corp, BrightWave Technologies, and Illumina Systems - are fictional aliases representing real-world applications of the Enterprise Health Program. Due to non-disclosure agreements (NDAs) and confidentiality requirements, specific company names and locations are withheld, but the financial and operational impacts are drawn from actual implementations in the lighting industry. Below are three examples illustrating its impact.

Lumina Corp: Boosting Efficiency and Engagement

Lumina Corp, a mid-sized lighting manufacturer with 1,000 employees, faced stagnant growth and high turnover. The Program's Enterprise Health Audit revealed low intrinsic motivation through the *Engagement & Retention Diagnosis* and organizational self-deception via the *Human Negative Self-Interest Diagnosis*, with leadership overestimating innovation capabilities. The Enterprise Health Transformation implemented leadership workshops, engagement programs, and process optimizations. Results included:

- 20% reduction in employee turnover, saving €1.5M annually in replacement costs (€50,000 per role replaced).
- 10% improvement in operational efficiency, streamlining workflows and boosting profitability.
- 15% increase in new product development, enabling faster market entry for smart lighting solutions by aligning leadership priorities and speeding decision-making by 30%.

This case highlights how the Enterprise Health Program turns inefficiencies into engines for growth, enhancing both financial and operational performance.

BrightWave Technologies: Maximizing Productivity and Compliance

BrightWave Technologies, a 500-employee LED component manufacturer operating across regions, struggled with miscommunication and regulatory pressures. The Enterprise Health Audit's *Time Management Diagnosis* pinpointed time lost to poor cross-department coordination, while the *Human Negative Self-Interest Diagnosis* revealed deeper collaboration inefficiencies and the *Psychosocial Assessment* uncovered workplace conditions hindering ESG

compliance. The Transformation's C-level workshops and talent optimization delivered:

- 20% reduction in production delays by streamlining communication, saving weeks in timelines.
- 10% increase in employee productivity, adding €2.5M annually in value through improved engagement.
- ESG compliance enhancement, reducing regulatory risks and avoiding fines up to €0.5M annually.

BrightWave's turnaround demonstrates the Enterprise Health Program's ability to address operational bottlenecks and align with sustainability imperatives, critical in today's lighting industry.



Enterprise Health Transformation (EHT) is a 3-12 month collaboration and deals with critical areas determined during the Audit.

Illumina Systems: Driving Efficiency and Leadership Alignment

Illumina Systems, a 1,900-employee lighting manufacturer, appeared successful but harbored hidden inefficiencies. The Audit's *Time Management and Greatness Diagnoses* revealed process inefficiencies and leadership misalignment affecting workflows. The Transformation's leadership coaching and strategic workshops delivered:

- 14% savings in annual working hours, equivalent to 3.5 million hours or €7M in cost savings, by streamlining operations.
- 30% faster decision-making, saving €0.5M+ annually in opportunity costs by aligning leadership strategies for quicker project delivery.
- Improved cross-department collaboration, reinforcing operational agility in a competitive market. Illumina Systems showcases how the Program uncovers inefficiencies even in high-

performing firms, translating diagnostics into multimillion-euro savings.

These examples illustrate the Enterprise Health Program's power to diagnose root causes - whether miscommunication, disengagement, or misalignment - and transform them into measurable financial and operational gains, tailored to the lighting industry's unique challenges. By uncovering hidden inefficiencies, EHP equips organizations to balance short-term demands with long-term goals, fostering efficiency and resilience. As disruption accelerates in the industry, such diagnostics become increasingly critical.

Future Relevance and Industry Impact

As the lighting industry evolves - with smart lighting, shifting legislation, AI, and IoT raising environmental complexity - internal organizational agility becomes critical. By streamlining workflows, breaking departmental silos, boosting engagement, and curbing wasted energy, the Enterprise Health Program indirectly equips companies to:

- *Foster innovation* in smart building and smart city applications, where lighting integrates with IoT for indoor and outdoor solutions.
- *Ensure workforce alignment* with technological shifts, enhancing responsiveness to market demands. The Program supports this indirectly by aligning leadership and teams with organizational goals - enabling visionary leadership to emerge, enhancing internal talent impact through skills like analysis, creativity, and the adaptability of experienced professionals over 50, and fostering a culture of continuous learning to match innovations like AI and IoT - building agility and resilience in a sustainability-driven market.
- *Optimize processes* to adapt swiftly, supporting sustainability goals like circular economy and Ecodesign as a natural outcome. Enhanced efficiency could save up to \$3.6 billion annually in energy costs through better lighting practices, as industry estimates suggest, building on the Enterprise Health Program's operational improvements - like the €7 million in savings from recent cases.

Adjacent industries like electronics, automotive, and clean-tech have established methods for optimizing efficiency. For example, electronics firms leverage technology integration, such as real-time analytics for supply chain efficiency, and agile methodologies like sprint velocity for inno-

vation cycles, while automotive companies use lean manufacturing techniques, including Six Sigma for defect reduction, to minimize waste. Through the Enterprise Health Program, lighting firms can adapt and implement these best practices more effectively by first aligning their internal structures, culture, and processes - ensuring that the adoption of such methods is seamless and maximally beneficial, positioning them as self-aware, change-resilient, and future-proof.

In an industry where smart lighting, regulatory pressures and technological disruption are rewriting the rules, waiting for inefficiencies to hit the bottom line is no longer an option. The lighting sector can't afford to lean solely on traditional metrics like financial KPIs or processual frameworks like Six Sigma - they miss the hidden cracks in culture, process, and execution that derail progress.

The Enterprise Health Program changes the game. Through the Program's core component - Enterprise Health Audit - it uncovers and measures inefficiencies before they spiral into costly setbacks. Through its structured Enterprise Health Transformation, it delivers measurable improvements - faster innovation cycles, leaner operations and a workforce aligned for success. This isn't just a tool; it's a new standard for staying ahead in a fiercely competitive landscape. Leaders who adopt EHP today will build organizations that don't just survive disruption - they drive it. Those who wait will scramble to catch up. Leaders must decide whether to address inefficiencies now or risk falling behind in a rapidly evolving industry.

Next Steps

Organizational health drives lighting industry success. Enterprise Health Program's tailored diagnostics and transformations unlock millions in savings and operational gains. Ready to explore how the Enterprise Health Program can transform your company? Start with a 30-minute Pre-Survey Interview or connect directly. ■



Wojtek Cieplik is a seasoned executive search and management consultant with over 20 years of experience in the lighting industry. His career spans the full value chain - from polymer chemistry for LED secondary optics to advanced optical solutions, semiconductor components (L1-L3 LEDs and sensors), and lighting fixture manufacturing - giving him a rare, 360-degree perspective on the industry's needs, challenges, and opportunities.

Wojtek has held key roles across Silicon Valley startups, European mid-sized enterprises, and global corporations, honing his operational acumen, cultural sensitivity, and ability to navigate complex organizational landscapes. This expertise shapes the Enterprise Health Program to tackle inefficiencies and boost performance in lighting firms.

Beyond technical expertise, Wojtek recognizes that strong leadership is the bedrock of great organizations. Alongside the Enterprise Health Program, his Executive Search services help lighting and semiconductor companies find leaders who align with strategic goals and values, adapt to digital enablement and sustainability imperatives, and blend technical expertise with leadership acumen. His straightforward, honest approach ensures these leaders meet immediate role demands while fueling long-term growth.

Wojtek Cieplik is an independent consultant, founder of LightGrow Consulting, and a Partner at Brandt & Partners, an international network specializing in Executive Search, industry-specific Business Consulting, and Talent Development. With B&P partners, he taps cross-industrial expertise - from production or quality optimization to supply chain resilience - to tailor solutions for lighting and semiconductor clients.

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Near-Infrared Light and Human Health: Exploring the Scientific Foundations and Practical Applications

Ayhan Siriner^{1,2} – CEO, Dr. Anne Berends – Co-founder & CTO,
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SunLED | sunled.health

SunLED studies the health effects of near-infrared light together with world-class universities such as Rijksuniversiteit Groningen, Maastricht University and University of Miami. SunLED has co-authored two papers and registered seven patents around the integration and usage of near-infrared light in every day environments.

SunLED Life Science offers their healthy light technology in the licensing program for companies to integrate near-infrared into everyday devices. That would ensure easy access to healthy light for everyone who is in need. As the important part of integration are the LED components, SunLED established the Qualified Supplier Program for their licenses to enable the purchase of high quality components to make the technology integration smooth. Recently SunLED signed agreements with the leading semiconductor manufacturers to join the Qualified Supplier Program: ams OSRAM, Lumileds and Luminus.

- ams OSRAM, a global leader in intelligent sensors and emitters with more than 100 years of industry experience, creates exciting innovations that enable its customers in the automotive, industrial, medical and consumer electronics markets to maintain their competitive edge and drive innovation.
- Lumileds has 50+ years of leadership in LED innovation and consistently sets standards in both performance and reliability with its exceptional lighting solutions.
- Luminus has spent the past two decades solving the lighting community's biggest challenges, including improving energy efficiency, light output, the quality of light, and longevity of its products.

Near-infrared light is already known to the lighting industry, but not so much for its healthy qualities. SunLED sees its purpose in creating awareness about the health benefits of sunlight and its vital near-infrared part. SunLED participated in CES

2025 as a part of Dutch delegation and has been called “the coolest Dutch start-up” by the press. SunLED will also join MWC in Barcelona and IFA in Berlin to attract attention to the problem of missing sunlight and to how they can solve that problem.

The Hidden Cost of Indoor Living: Sunlight Deficiency

Humans evolved over centuries under the sun, yet modern life has confined us indoors. Homes and offices provide such comfortable conditions that we now spend approximately 90% of our active hours inside. However, as we embrace indoor living, we are beginning to realize a critical downside: a lack of sunlight has a serious negative impact on our health.

The Mental Health Crisis and the Role of Sunlight

Recent studies confirm a strong link between daylight and overall well-being, highlighting the significant impact of natural light on mental health. Scientific research increasingly shows that exposure to natural daylight plays a crucial role in mood regulation, boosting sleep quality, and reducing the risk of anxiety and depressive disorders. Prolonged periods without sufficient sunlight—especially during the dark winter months—can lead to seasonal affective disorder (SAD), a condition characterized by persistent fatigue, lack of motivation, and low mood. A notable study on operating room nurses—who work long shifts



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under artificial lighting—demonstrated the profound effects of limited sun exposure. Nurses with minimal access to natural light reported significantly poorer mental health compared to those with greater daylight exposure. The findings suggest that even small increases in sunlight exposure can lead to measurable improvements in mood and overall mental resilience.

Sunlight in the Workplace

The implications of sunlight exposure extend to the corporate world. Employees who spend long hours indoors, often under inadequate lighting, may experience reduced cognitive function, lower energy levels, and decreased productivity. Studies show that natural light enhances mood, attention, cognitive performance, sleep quality, and physical activity—all crucial elements for optimal workplace performance.

Forward-thinking companies are increasingly recognizing the benefits of investing in employee well-being, with substantial financial returns. Data indicates that organizations prioritizing workplace wellness enjoy significant advantages:

- Healthier employees tend to stay longer, reducing costly turnover.
- Improved employee well-being generates financial returns equal to 17–55% of annual salary.
- The largest gains (54–77%) come from enhanced performance and fewer employees working while unwell.

Sunlight Matters More Than You Can Imagine

While its impact on mental health is widely acknowledged, the role of sunlight in physical well-being is just as crucial. Research links insufficient daylight exposure to an increased risk of cardiovascular disease—one of the leading causes of mortality worldwide. Inadequate sunlight has also been associated with a higher likelihood of developing autoimmune diseases, as natural light helps regulate immune function.

Who is at Risk of Sunlight Deficiency?

The short answer would be – almost everyone in developed countries. Diving deeper into the topic we can highlight some categories that are most likely severely deprive themselves from sunlight:

People in the areas with dark winters.

Desperate need for sunlight is probably most familiar for people living in Canada, the northern part of the US, UK, Nordics and other countries within a similar latitude. Millions of people Google “Winter depression” or “Winter blues” starting from November, spiking in January and dropping down in March.

Office workers. But even if the sun is shining outside, you might still not be safe from sunlight deficiency. In order to get the most out of sunlight, particularly the healthy near-infrared light, a person needs to be outside on a sunny summer day for 15-30 min. Near-infrared light coming from the sun is not reaching you when it is filtered out by our window glazing. So even if you see sunlight, it won't give you its benefits when you are trapped in the office.

People in areas with high air pollution.

Another reason for a healthy near-infrared light to not reach people is if the dense air pollution blocks it. Countries like China, which emits 11.9 billion metric tons of CO₂ annually, face growing concerns about the effects of limited sunlight exposure.

How Sunlight Makes Us Healthier

Sunlight consists of a broad spectrum of light, including ultraviolet (<400 nm), visible (400–750 nm), infrared (>1,400 nm) and near-infrared light (750–1,400 nm). Each type of light plays a different role in human health. UVB rays are essential for the production of vitamin D, however excessive UV exposure can be harmful, increasing the risk of skin damage and cancer. Meanwhile, visible light helps regulate our circadian rhythm, improving sleep patterns. The readership of LED professional Review is probably well aware of the health benefits of human centric, circadian, or biodynamic lighting. This type of lighting uses careful tuning of visible light (both spectrum and intensity) to keep the biological clock entrained. The mechanism of this effect travels via the retinal ganglion cells in the eye that communicate with the suprachiasmatic nucleus (SCN) in the brain. While this biological effect of visible light is important for our health and wellbeing, it is not the only type of light that our bodies need in order to stay healthy.

Invisible near-infrared light induces a biological effect called photobiomodulation. Its working mechanism relies on the activation of mitochondria, also known as the powerplant of our cells. In doing so, photobiomodulation energizes our body with

a plethora of positive effects. Research since the 1960's [1] has revealed that (far) red or near-infrared light has beneficial effects on a variety of medical conditions, like accelerated wound healing, [2] mitigation of diabetes type II symptoms, [3–7] improved brain function, [8–13] reduction of depression, [14–18] and promotion of eye-health. [19–23] This broad scope of impact is not surprising when one realizes the fundamental role that mitochondria have in our body's energy management and metabolism; processes that form the foundation of every cell function.

Unveiling the Mysteries of Near-infrared

When knowing the big impact that near-infrared light can have on diseases, it is only a small step to realizing that this light can also help the general population to stay healthy, fit, and happy. Indeed, recent scientific studies on generally healthy people show that both their physical health and mental health improve when they are exposed to near-infrared light in the indoor environment. In an earlier edition of this magazine, we have highlighted the results of the clinical study performed by Chrono@Work and the University of Groningen published early 2023. [24] This study showed that a dose of 6.5 J/cm² of 850 nm light, significantly reduced the resting heart rate, improved mood, reduced drowsiness and reduced systemic inflammation. More recently, another study was published by a group of Canada based researchers, in which 150 healthy participants received 5 J/cm² near-infrared light (a mix of 735 nm, 875 nm, and 960 nm). [25] They also found impressive results on cardiovascular health and mental health, both as acute effects after exposure to near-infrared light.

The concrete results reported were [1]. Increased resting high-frequency heart rate variability (HF-HRV): This indicates improved physical fitness and better cardiovascular health; [2]. Decreased HF-HRV during cognitive demands, this indicates enhanced physiological flexibility to adapt the body to mental demands; [3]. Enhanced feelings of pleasure & better emotional state maintenance (mood), near-infrared light had a protective effect in maintaining pleasure levels and preventing the decline in mood over the 2-hour period during which participants performed various tasks, including cognitive assessments. While these two studies differ on the exact light recipe, the core message of near-infrared light improving mental and

physical health of a generally healthy population is evident.

Another aspect in which these two studies differ from the medical treatment cases is the systemic approach. While most photobiomodulation research is focused on direct irradiation of the problematic area (either the skull, the wound, the painful joint, etc.), both Gimenez et al. [24] and Roddick et al. [25] irradiated people during their daily routine, i.e. with their face, neck and possibly hands exposed, yet measured systemic (i.e. full body) health effects. These results can be rationalized by the deep penetration of near-infrared light through the skin (Figure 1), allowing to reach deeper lying cells that, when activated, transmit molecules in the body's transportation channels, finally leading to full body positive effects. The apparent evidence of this systemic photobiomodulation effect motivated us to research how skin cells respond to near-infrared light, as we suspected those cells to have a crucial role in the mechanical pathway.

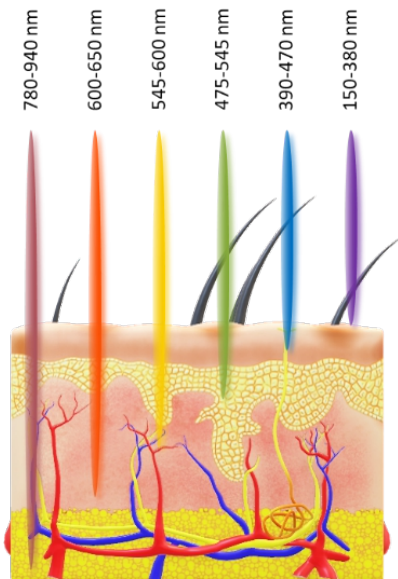


Figure 1: Wavelength dependent light penetration through the skin, near-infrared is known for its deep penetration. [26]

The two most abundant skin cell types are keratinocytes (the most upper layer of the skin) and fibroblasts (deeper in the skin). A study by Van der Vloet et al. [25] shows that when these two cells are exposed to 6.5 J/cm² 850 nm light, the fibroblasts show a significant response, while the keratinocytes don't. The changes in the lipid metabolism of the fibroblasts are via pathway analysis related to inflammatory and immune responses. This observation hints that the response of skin cells to near-infrared light can indeed affect systemic inflammation. Moreover, the finding that only fibroblasts show a significant response,

support the hypothesis that near-infrared light is ideally suited to activate the deeper layers of the body and induce systemic health effects. Of course, more studies are essential to understand the full mechanistic pathway, including the role of skin cells, in the systemic effects of near-infrared light on our bodies.

Natural Near-infrared Light

The natural abundance of near-infrared light differs greatly depending on weather conditions, seasons, time of day, latitude, etc. These large variations become clear in Figure 2 that shows that the near-infrared irradiance on the ground in the Netherlands at midday has a bandwidth of 0.2–9.1 mW/cm². It is needless to mention that in the mornings and afternoons the intensities drop compared to the values at midday.

The natural irradiances also put the effective doses described in the studies discussed above in an interesting perspective. A dose of 6.5 J/cm² is achieved in 12-15 minutes on a sunny day around midday, while it requires an hour on a cloudy summer day at midday, and is virtually impossible on a cloudy winter day.

Add Value to Your Product

When the effective light recipe is known, the design of a product that delivers this light recipe in the most effective way becomes easy. The most important use-case characteristics are schematically depicted in Figure 3. Additionally, the available space for integration and the power available can be factors to take into account. From this use case definition, the design specification follows: based on the distance and the area the beam angle is

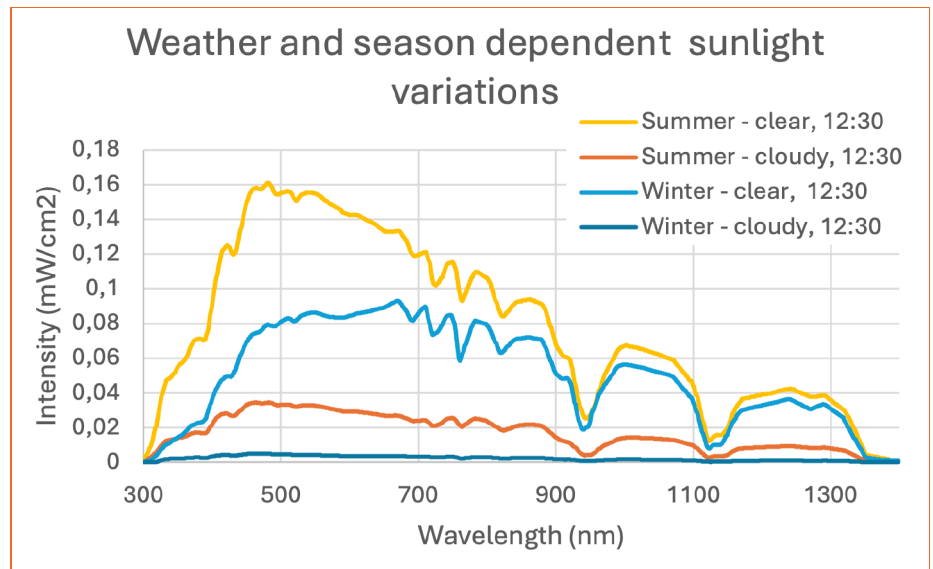


Figure 2: Illustrative solar spectra for a winter and summer day at midday, both on a clear and a cloudy day. The figure shows the large differences between near-infrared irradiance reaching the ground on these days. On the clear summer day, the irradiance in the 800–900 nm spectral window is 9.1 mW/cm², while on the cloudy day it is 2.0 mW/cm². As expected the overall power in the winter is lower, with an irradiance of 6.9 mW/cm² at midday in the 800–900 nm spectral window, and only 0.2 mW/cm² on the cloudy winter day. Data from Van Sark [28].

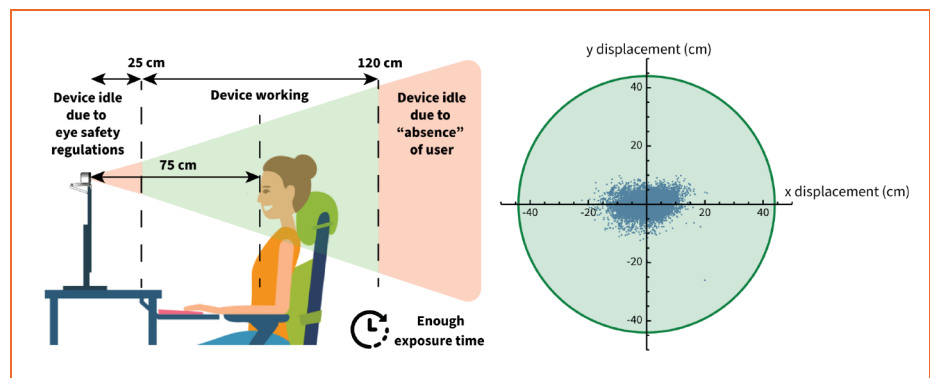


Figure 3: The most important use-case characteristics are shown schematically.

determined, while the distance and the time are the most important parameters to determine the driving conditions and number of LEDs. For the latter, high quality high-power near-infrared LEDs are recommended, like the ones supplied by our Qualified Component Manufacturers ams Osram, Lumileds, and Luminus Devices.

A real life example of implementation and how compact it can be is the SunBooster: a USB-powered device that can be clipped on any monitor or laptop screen (Figure 4, Figure 5) This device is designed to deliver a dose of 6.5 J/cm² at an average distance of 75 cm over the course of 3h, i.e. perfect for any office use case. As the behavior of people working at a screen is very static, we can use very narrow beam angles to increase the efficacy: all electricity is converted into meaningful photons. As a result, the average power draw of the SunBooster is only 4.2 W.

For the past century human lives have changed drastically making our lifestyle

completely different from the one we had for thousands of years. We disconnected from nature and outdoor living, forcing our bodies to adapt. How can we keep ourselves healthy in such conditions? Should we go back to how we used to live? SunLED finds the answer in technologies. With technologies grounded in science and created with care we can enjoy the comfort of our homes without having to compromise our health and well-being.



Figure 4: This USB-C-powered device delivers targeted doses of near-infrared (NIR) light—an essential part of sunlight you miss indoors—proven to enhance mood, energy, and immunity.

Summary

SunLED collaborates with top universities to study the health benefits of near-infrared (NIR) light, co-authoring research and securing patents. The company offers a licensing program for integrating NIR into everyday devices, supported by its Qualified Supplier Program with ams OSRAM, Lumileds, and Luminus. SunLED raises awareness of sunlight’s health impact, highlighting how modern indoor lifestyles contribute to deficiencies linked to mental and physical health issues. Scientific studies confirm NIR’s benefits for mood, cardiovascular health, and inflammation reduction. SunLED showcases its innovations at major global events and promotes NIR solutions like the SunBooster, a compact device designed to counteract sunlight deficiency. The company envisions technology-driven solutions to bridge the gap between indoor living and natural light exposure. ■

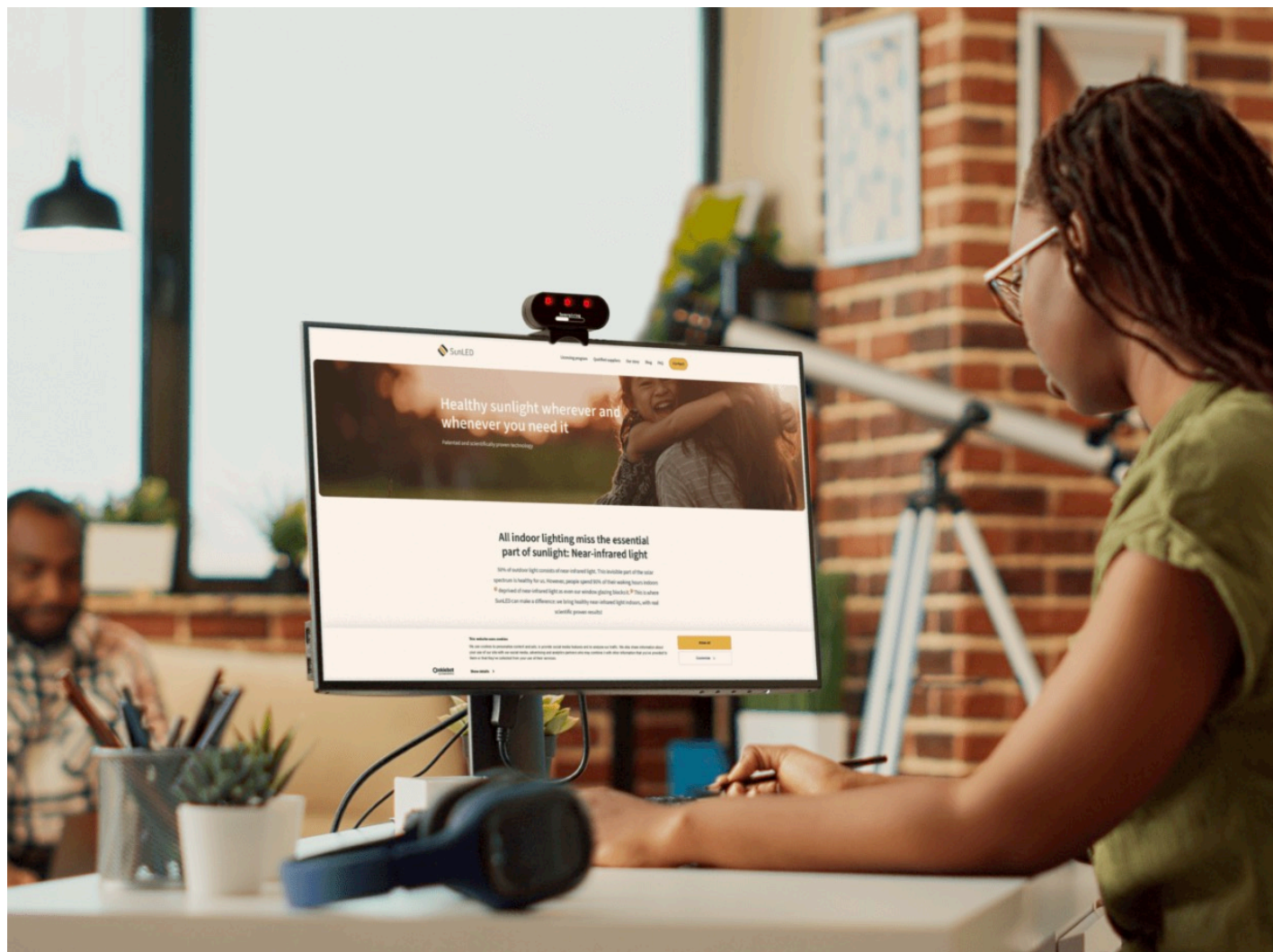


Figure 5: A real life example of near-infrared technology implementation and how compact it can be is the SunBooster.

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"Today's modern lifestyle hinders people from exposure to the very driver of life on Earth — sunlight. I am very happy leading SunLED Life Science into a successful future where we make indoor living healthier!"
 – Ayhan Siriner, CEO



"People worldwide don't get enough sunlight, and it can have serious systemic health consequences. Therefore, we strive to create a scientifically proven, accessible, and energy-efficient solution that would mitigate sunlight deficiency."
 – Dr. Anne Berends, CTO and co-founder



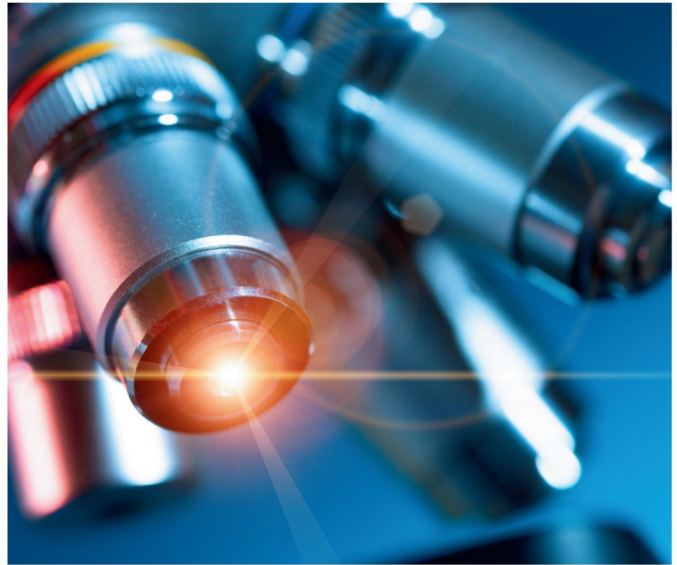
"Being part of SunLED is doing something meaningful that changes people's lives for the better. SunLED technology is made by professionals who care for everyone in need."
 – Aleksandra Goncharova, Marketing & Communication Officer



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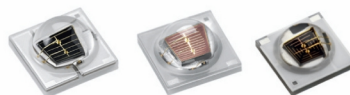
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Streetlights Will Become the Location of Choice for Sensors and Communication Modules

Jonathan Catchpole, System Architect at TE Connectivity and
Martin Creusen, Standards and Regulation Professional at Signify

A recent article published in LED professional Review³ from the Zigurat Institute spoke about a survey they had conducted on Zhaga-D4i control and sensor devices. Zigurat had identified 41 suppliers of control and sensor devices, with 21 responding to their survey. In the article, the study recognizes the pivotal role that Zhaga Book 18 and the Zhaga-D4i certification process is playing in shaping the future of public lighting and concluded with a series of recommendations about greater stakeholder engagement.

The Zhaga Consortium was founded in February 2010 with the aim to establish industry specifications of interfaces for components used in LED Luminaires. Specifically, Zhaga Book 18 defines the mechanical and electrical interface between a 'Zhaga connector' (**Figure 1**) and the Luminaire Extension Module. It thereby helped to drive the Zhaga-D4i ecosystem around 'D4i drivers'.

Streetlights have a long functional life of typically 20 to 25 years, during which the core functionality of lighting the roads and streets beneath it won't change with the possible exception of adding dimming capability. As technology moves forward relentlessly and with such a long product lifetime, why not make it configurable and easily upgradable. Control devices can create further energy savings beyond using LED light sources and as the Zigurat Institute study notes, streetlights are a great location for smart city sensors and devices. Being a regularly positioned power supply with a unique vantage point of a city, Zhaga's Book 18 modular system architecture facilitates easy field-upgrades and adaptations. This lighting system flexibility is especially relevant in the smart city arena, where streetlights are playing an essential role, because of their mains power connection and dense pole distribution. Extending the basic lighting functionality of streetlights with tasks like traffic or air quality monitoring is just the tip of the smart city iceberg and is only limited by people's creativity to imagine new applications.

During the lifetime of a streetlight, thanks to standardization, it can now be upgraded or adapted once or multiple times during its lifetime. This allows for smart city devices to be rolled out across multiple budget cycles. Similar scenarios are valid for sensor functionality, which can be added at the

time of installation or later adapted during the functional life of the streetlight. The mentioned connectivity and sensor fields of technology are already quite dynamic and new technologies are expected to appear in the coming years and decades. Associated use cases are similarly dynamic and range from straightforward lighting control, lighting asset management to maintenance and early warning propositions. Again, the range of current and future options is not constrained and will only extend further when new technologies evolve. This is why the Zhaga-D4i certified luminaire is so important as the 'future proofed' platform, with its standardized interconnect interface, wiring structure, communication protocol and power budget. As shown in **Figure 2**.

This now makes certification a very important aspect for the market. The Zigurat institute's article spoke about a reluctance for node manufacturers to certify their products. This was the view of the node manufacturers and not an end user view. Node manufacturers have traditionally not needed to certify their products, beyond electrical safety.

Zhaga-D4i Certification

Certification is crucial from an interoperability point of view. Certification gives the benefit of knowing the devices comply and will be interoperable in the larger system giving an extra layer of confidence. Benefits of certification also include reduced testing efforts for users and making second sourcing much easier. Thereby, tender specifications play an essential role; by requiring Zhaga-D4i compliance interoperability between modules and luminaires is ensured and outdoor systems do not need additional testing by specifiers and installers.



<https://zhagastandard.org>

³LpR#107, Jan/Feb 2025; https://www.led-professional.com/downloads/lpr107_full_93711.pdf



Figure 1: Zhaga connector and luminaire application.

The Zigurat article mentioned that they have seen a certain reluctance for node manufacturers to certify their products. The current status of luminaire certification is steadily growing with more than 400 luminaire families having been certified. This confirms the market need for long-term interoperability of streetlights and the need for peace of mind when installing outdoor lighting systems with a long lifetime of 20-25 years.

Certification of communication and sensor modules is also progressing with around 50 nodes having been certified. Book 18 has been written to benefit the end user, making it so much simpler for them to specify interoperable products from dif-

ferent manufacturers. They no longer must write lengthy tender documents detailing things like the connector interface, power budgets, intra-luminaire communication protocol, switching and dimming methodology, to name a few. Tender documents now only need to list that products will meet the requirements of Zhaga Book 18 and be Zhaga-D4i certified.

Public tenders should value these benefits by mandating that modules are being certified according to Zhaga Book 18 and the corresponding D4i protocol.

Zhaga Book 18 enables the potential for a large range of module types like lighting control modules which set the right light

levels depending on ambient light level, traffic or weather conditions. These can either be stand-alone or centrally controlled by a central management system. Other applications could include using the light system as an indicator or warning system. But as we are seeing now, a category of smart city sensors are emerging that don't affect the light output, but purely make use of the streetlights position and power supply. Applications such as climate, pollution or traffic sensors are using this Zhaga-D4i platform to offer more affordable solutions compared to traditional devices which need their own power supply, communication and mounting arrangement. As the Zigurat institute stated, Zhaga-D4i is a cost-effective way of citywide sensor deployment. Certification of this last category of modules is especially beneficial as it guarantees that modules are interoperable with the lighting host system. It also ensures that other modules linked to an outdoor luminaire are not impacted and the overall system runs flawlessly.

To ensure peace of mind to end-users who need to make long-lasting decisions, a modular approach based on a connectorized solution has been developed. Interoperability of streetlights and the related ecosystem of connectivity and sensor modules is of key importance. This has been the main goal of the Zhaga-D4i standardization effort from the first publication of Zhaga Book 18 in November 2017 (Figure 3).

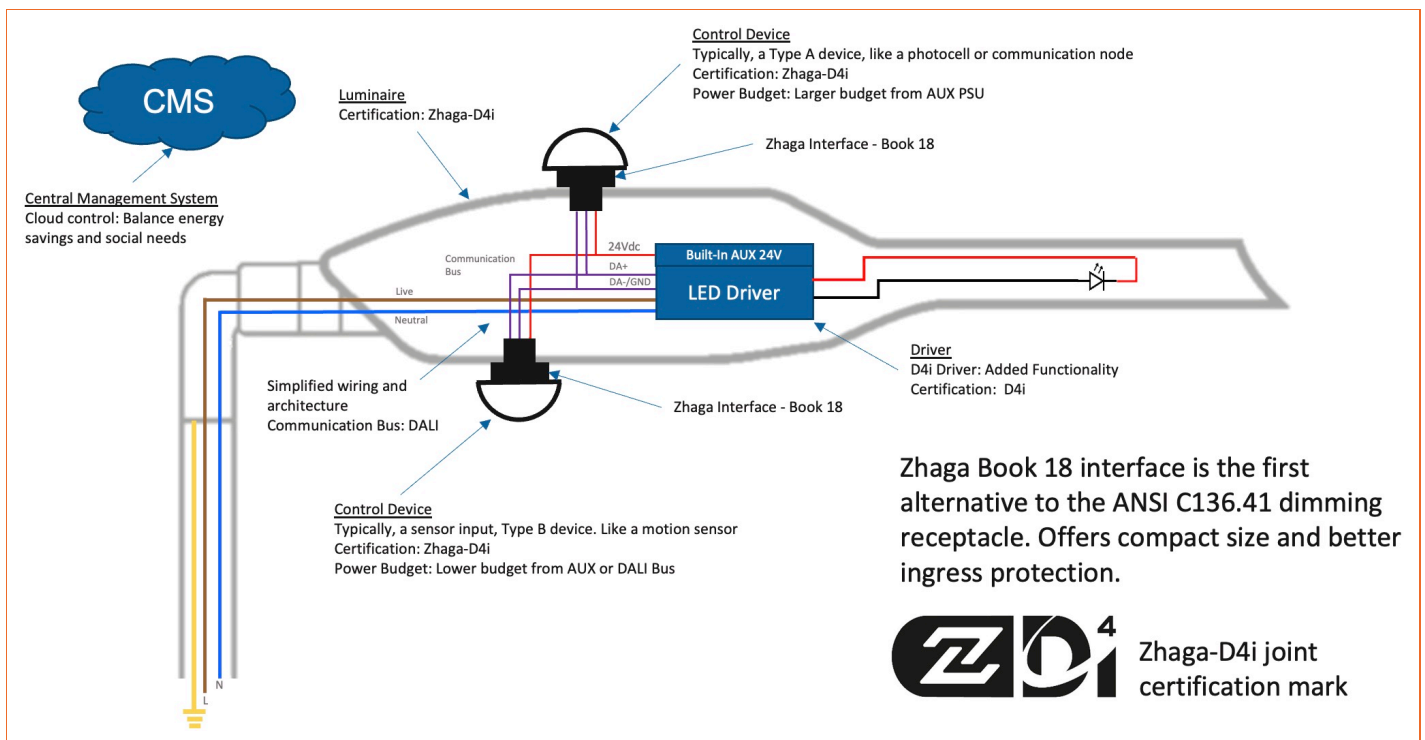


Figure 2: Driving the two node architecture, the standardization and certification program benefits specifiers, allowing them to specify products from different manufacturers and know they will work together.

Zhaga-D4i Scope

The first edition of Zhaga Book 18 defined the mechanical fit system and the electrical pin assignment in order to ensure the interoperability between the luminaire extension receptacle (LEX-R) and a single luminaire extension module (LEX-M). The DALI protocol was selected to enable the LEX-M to control the electronic control gear in the luminaire. Mechanically, the new fit system was based on a compact and cost-effective LEX-R interface allowing the different LEX-M modules to be flexibly mounted, both on top- as well as on the bottom-side of luminaires. How to mount the LEX-R to the luminaire or how to connect the driver inside the luminaire was not restricted, if the ‘keep-out’ area was met, to ensure sufficient design freedom for luminaire OEMs as well as LEX-R manufacturers. Regarding the wireless connection of the luminaire, via the LEX-M to the central management system (CMS), no constraints were set in the Zhaga-D4i specification.

In the second edition of Zhaga Book 18, the system architecture for a dual LEX-M system was defined including the allowed power budget and the hierarchy setting for two LEX-M types: Type A and Type B (Figure 2). The power budget consisted of a maximum current consumption from the DALI bus and a separate average and peak power consumption from the 24V auxiliary supply. Plug-and-play functionality was guaranteed for maximum one Type A LEX-M and maximum one Type B LEX-M

mounted to the luminaire. In this context, ‘Plug and Play’ means that the datasheet specification of the LEX-M is guaranteed. It does not define any minimum performance levels, such as response speed or sensor sensitivity.

In the third edition of Zhaga Book 18, an additional form factor was added to the existing LEX-R form factor. This allowed hybrid luminaire architectures combining LEX-M modules as defined by ANSI C136.41, in Book 18 called N-LEX-M, with the already defined Z-LEX-M modules. Again, to ensure interoperability, the N-LEX-M modules shall meet the requirements of the Type A specification and only maximum one of each module type is allowed for each luminaire.

At Zhaga we are now working on edition 4 which will bring Book 18 to decorative and heritage luminaires.

Limitations

As stated, in the article from the Zigurat Institute, Zhaga Book 18 doesn't limit the wireless communication protocols that can be used nor does it stipulate that either a Type A or Type B device can contain the radio module. But the Zhaga-D4i system does have constraints that could limit any wireless communication. The original intent of the system was that the Type A device would contain the radio, so it was given the larger share of the AUX power supply budget: 2W average and a 5W peak for a short

period of time. Enough to send packets of data to a gateway or base station. Though Book 18 doesn't state a radio can't be placed in a Type B device, the power budget for those devices is 1W max from the AUX power supply or 46mA from the DALI bus.

The mega trend is for devices to consume less power. We only need to look at Apple's design philosophy, creating their own silicon for their devices to be able to process data and commands more efficiently. Hence with a reduced energy consumption. To this end, Apple stopped publishing battery sizes for their devices as it became a redundant measurement. At Zhaga, we have members that are pushing the limitations of this Type B power budget by adding cameras, video analytics, and AI. All power-hungry processes, yet they can meet the power budget. We're not aware of anyone putting a radio module in a Type B device, but there are plenty of power efficient communication protocols out there that could be used.

Another limitation raised by the Zigurat's article is the bandwidth of the DALI communication protocol. It is true that DALI is limited to 1.2kbps, it was designed this way just to be reliable as well as to utilize low-cost transceivers, use a wide range of cable types and allow for the DALI bus to carry power. DALI was designed to be efficient with using commands to complete driver functions, but the use of memory banks is incredibly powerful. Sensor data can be written to these memory banks,

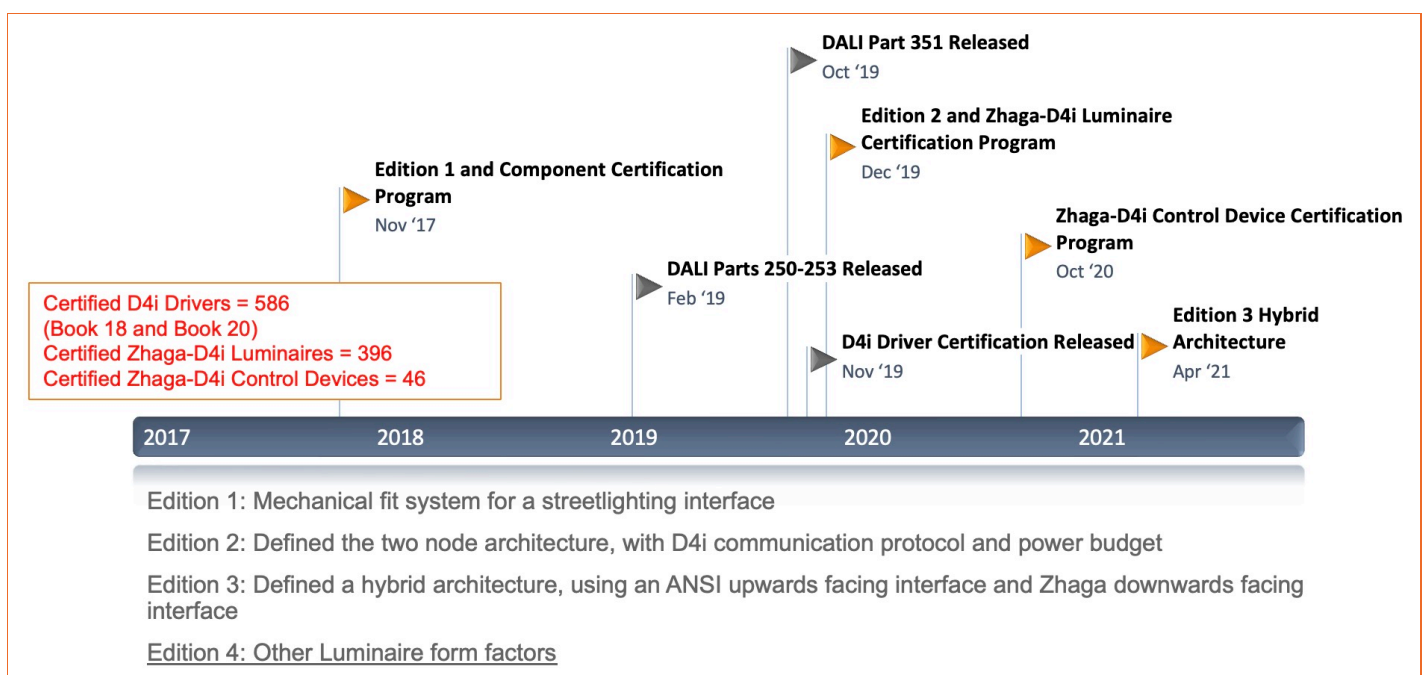


Figure 3: Zhaga Book 18 history/timeline.

read out across the DALI bus and communicated wirelessly to the cloud. No, you won't be able to collect hours of sensor data or streaming video and beam it to the cloud for a high powered AI machine to process the information. If a solution demands this approach, then a radio module in the same device as the sensors is probably the right route. On the other hand, Zhaga-D4i facilitates end users/owners of streetlights to connect their streetlights to a wider network for relatively low costs. This has been because of very small packs of information sent very infrequently. It would be a steep change to now ask them to pay large sums in connection charges to communicate large amounts of data to the cloud.

Liaisons

Interoperability is at the core of what Zhaga has been trying to achieve with Book 18. The desire to turn streetlights into a smart city platform that allow different manufacturers to create different parts of the ecosystem, and work seamlessly together. Zhaga started this journey as a single consortium when we released edition one of Book 18. As stated, this defined a mechanical interface, a receptacle, that control devices could be plugged into and control the driver with a focus on the low power nature of LED light sources.

But this was far from a complete solution. To build this complete solution we needed to define the wiring architecture, power budget and communication protocol. For the latter, the DALI protocol was the obvious choice, but there was no hierarchy built into the DALI protocol. Zhaga Consortium and the DALI Alliance formed a liaison to work together to create edition 2 of Book 18, the Zhaga-D4i ecosystem and a Zhaga-D4i joint certification program. This has served the market well and really aligned well with the needs of the end user, allowing them to create tender documents without having to carefully detail many requirements to ensure that different parts of the system worked together and were interoperable. The certification program is that assurance for the end user, knowing that the products they purchase are tested and independently verified according to the standard.

This same certification value is why ANSI in North America are working with Zhaga and DALI to bring Zhaga-D4i to their standards. The C136 technical working group, of ANSI, creates standards for the North American market. However, the ANSI structure doesn't allow for a certification

program as their end users are usually the power utility companies. Currently when selecting a product to use in their network they test it themselves to ensure compliance. An expensive and timely endeavor, especially if testing with a myriad of possible combinations, but for mechanical and analogue products it was often manageable. As the world moves towards digital devices with a lot more functionality this testing process now gets infinitely more complex and would require the use of a software test bench. It would be much simpler for ANSI to simply reference Zhaga Book 18 and the Zhaga-D4i certification process.

The latest liaison which Zhaga is involved with is between DALI, TALQ and Zhaga. Between the three organizations we own almost the whole of the end-to-end solution from the driver or sensor to the cloud platform. And yet the flow of data, commands or configurations aren't unified. Work is underway to change this.

As in all Zhaga Books, in Zhaga Book 18 the promise of interoperability between luminaires and the different module types is assured through joint certification by accredited test houses. A corresponding logo licensing program for both luminaires as well as modules helps to communicate the interoperability message towards end-users. Certification of products is possible for regular and associate members. Every end user can find an overview of certified products on the Zhaga website, with no Zhaga membership required to get access to this product certification database.

Further widespread adoption of Zhaga-D4i certified smart city modules, both sensors as well as connectivity nodes, is not hampered by any restrictions in wireless communication protocols or sensor technologies. End users like cities or power utility companies could benefit from the key advantages provided by the Zhaga-D4i certification program when public tenders would value these benefits by mandating that modules are being Zhaga-D4i certified. ■

The Zhaga Consortium⁴ is an industry association with some 600 members that publishes industry standards for interfaces of LEDs and other components inside lights. One of its industry standards, Zhaga Book 18⁵, addresses the interconnection of components in outdoor lighting.

⁴<https://zhagastandard.org>

⁵<https://zhagastandard.org/books/overview/smart-interface-between-outdoor-luminaires-and-sensing-communication-modules-18.html>



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Understanding and Implementing Interoperability

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Often considered a ‘holy grail’ by many in the lighting industry, interoperability suffers from the same challenges as many other technical terms—it means different things to different people. So, what exactly is interoperability? And why has it been so sought after for so many years? In general, non-technical terms, interoperability is the notion that different devices—programmable LED drivers, sensors, emergency units—will work seamlessly together, one can simply ‘plug’ devices together and ‘play’ them. As for the ‘why’, interoperability offers numerous benefits, providing greater design and installation flexibility at the time of initial installation as well as into the future. In addition, this also offers greater customer choice. Let’s take a closer look at what this actually requires from a lighting controls perspective. There are different levels of interoperability, each of which this paper will explore in detail later. These levels include:

Device Level

How different devices (i.e., driver, sensor) will physically fit together, regardless of the manufacturer. For instance, the way a sensor or controller fits into a lighting fixture involves the form factor of the devices as well as how one device attaches to another.

Intra-network Level

How different devices communicate with each other on the same network, whether that be wireless-wireless, wired-wireless or wired-wired.

Network-network and Cloud Interoperability

How different networks communicate with each other across multiple building systems and third-party networks or clouds. This is frequently considered to be integration, rather than ‘pure’ interoperability, as different building systems (i.e., Building Management Systems (BMS) or access control systems) use significantly different protocols, and communication between them generally requires a gateway or other bridging device.

Currently in North America, networked lighting controls (NLC) account for a small percentage of installed controls. In its 2022 Solid-State Lighting R&D Opportunities report, the US Department of Energy, Office of Energy Efficiency and Renewable Energy, estimated that less than one percent of all luminaires in the US were ‘connected lighting’ [1]. More recently, the Design-Lights Consortium has offered estimates of market penetration of NLCs as being in the 5-10 percent range for commercial buildings [2]. The opportunity in energy savings alone is vast, with savings estimates averaging near 50% [3]. Add in additional savings from integration with other building systems, such as HVAC, and the estimates are even higher.

Non-energy benefits may be even more significant, however, and this is where the value of interoperability for wireless NLC is most pronounced. With the ability to design and deploy a custom solution from a range of best-in-breed components, customers can bring much-needed flexibility to their budgets as well as to their planning timelines. No longer does a controls project need to be completed in a specific timeframe; project phases can be accommodated over a single budget cycle or multiple cycles without sacrificing functionality.

Furthermore, this flexibility in timing, design and deployment is particularly valuable in retrofit situations, where owners/operators of small or midsize facilities face rising energy costs while struggling with a lack of technical expertise or capital funding for costly lighting and controls upgrades. More than half of the commercial buildings in the US were built between 1960-1999; only 25% were built after 2000 [4]. Many of these buildings are modestly sized; according to the 2018 CBECS, 71% of commercial space in the US consisted of facilities 10,000 square feet or less. The versatility inherent in interoperability provides a toolkit of solutions for a range of building budgets and vintages.

The emergence of building performance standards (BPS) for existing buildings may

also present an opportunity for deploying more wireless NLC. Focused on improving energy performance in existing buildings, BPS set long-term performance targets for buildings without specific rigorous prescriptive requirements for achieving those targets. Using a flexible NLC solution bundled with a lighting upgrade can help building owners/operators to comply with these standards.

Exploring the Layers of Interoperability

Device Level Interoperability

At this mechanical interface level, interoperability means that different devices will physically fit together, regardless of manufacturer. For instance, the way a sensor or controller fits into a lighting fixture involves the form factor of the devices as well as how one device attaches to another. Two of the most common standards for mechanical interoperability are those from the Zhaga Consortium, a global lighting industry consortium that develops and promotes standards for LED lighting components, and those from NEMA, the National Electrical Manufacturers Association, a US-based trade association that develops standards for various types of electrical equipment, including LED-based luminaires (Figure 1).

The Zhaga standards focus on defining standardized interfaces for LED lighting components, such as control modules and other components. Book18 describes a smart interface between outdoor luminaires and sensing/communication nodes, specifying power and communication aspects in addition to the mechanical fit and electrical pins [5]. Book 20 defines a smart interface between an indoor LED luminaire and a sensing/communication node [6].

NEMA Standards focus on defining specific product characteristics. For instance, NEMA LS 20000-2021 provides recommended mechanical shapes and minimum keep-out area dimensions for indoor luminaires to interface with luminaire integrated

control devices [7], while ANSI C136 provides standards for roadway and area lighting equipment. At this level, the greatest benefit for interoperability is speed of installation, particularly with outdoor lighting. Because the standards enable ‘click on’ installation with minimal or no wiring, contractors can retrofit a project devoting only a couple of minutes per fixture. The customer also benefits from the possibility of phasing in advanced controls more conveniently over a large project if funding is a concern. By selecting an open standard approach, the customer can order different luminaires over time without concerns about control compatibility.

Intra-luminaire Interoperability

Inside the luminaire, in addition to the standardized mechanical interface described above, an open standard communication interface enables free-flowing communication between the components within a luminaire, such as drivers and embedded control devices. The DALI D4i standard, an extension of DALI-2, establishes specific criteria for data and power transmission between devices inside the luminaire. While DALI-2 standardizes the interface for intra-luminaire communication; D4i standardizes the feature set of the LED driver. This provides a way to extract data from components inside the luminaire such as energy or occupancy monitoring. PoE provides standardized data communications and power supply to components within a luminaire via Ethernet cable.

The greatest benefit from this level of interoperability, available from a full stack standard⁶, is the ability of a user to extract valuable data from inside the luminaire, such as energy reporting or occupancy monitoring without the need for intermediate gateways or translators. Because of the open standard inside the luminaire, the customer can scale more easily in the future as well as broadcast future functionality updates to the intra-luminaire components.

Network Interoperability

Across the control network, the open standards approach involves the way devices communicate, whether they communicate wirelessly between themselves, are physically wired together for communication, or

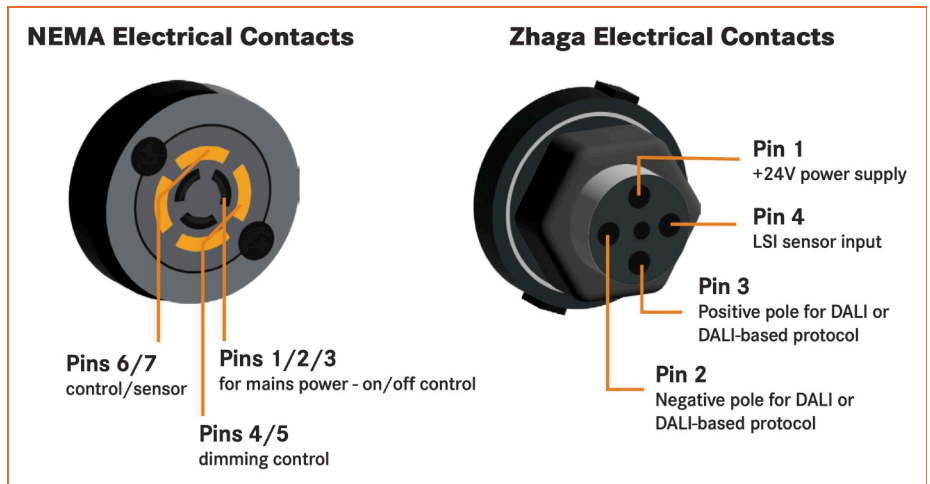


Figure 1: Comparison of NEMA and Zhaga mechanical interface standards.

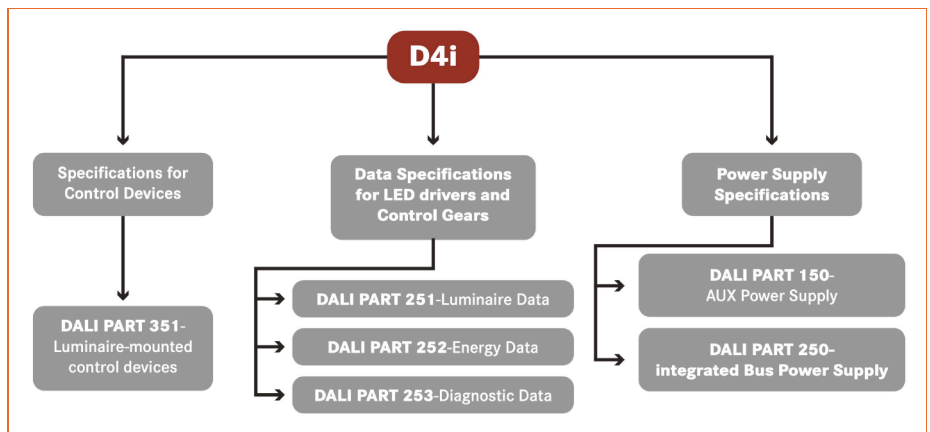


Figure 2: DALI D4i features.

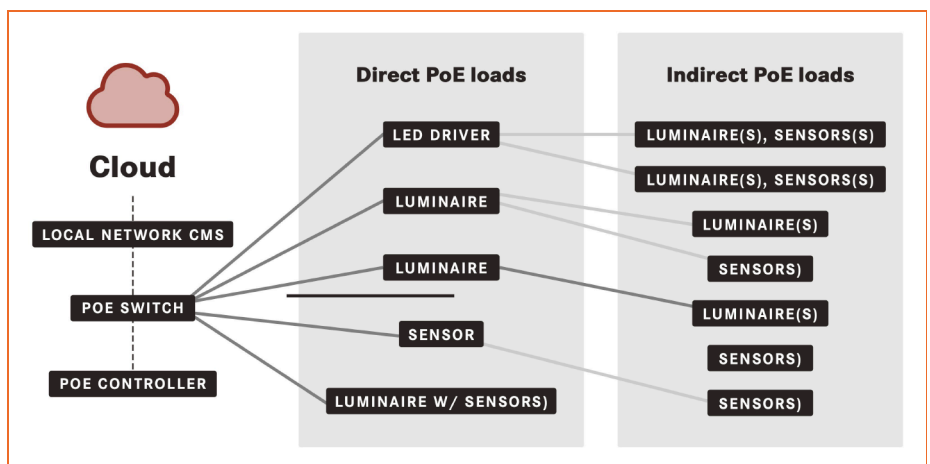


Figure 3: Visualization of how PoE works. Image credit: US DOE PoE Lighting System Energy Reporting Study Part 1, February 2017.

⁶A full stack standard is one that provides standardization for the device/application layer in addition to defining the transport/communication layer(s).

some combination of both. Common wireless standards include:

- **Bluetooth NLC**
Bluetooth® NLC (Networked Lighting Control) is a full-stack standard for wireless lighting control, providing standardization from the radio through to the device layer, providing a set of device profiles that standardize the control of smart lights, sensors and control interfaces.
- **Zigbee**
Zigbee is an IEEE 802.15.4-based specification for high-level communication protocols used to create personal area networks with small, low-power digital radios. The specification is full stack, but there may be private vendor extensions or modifications that make full interoperability challenging.
- **Matter/Thread**
Thread, a low-power, low-bandwidth, full stack mesh networking protocol that uses the 802.15.4 radio technology, is specifically developed to improve connectivity between products, using a mesh network, so devices communicate with each other without the need for a central hub. Matter is an application layer that runs on Thread.
- **WiFi**
WiFi is a family of wireless network protocols based on the IEEE 802.11 family of standards, commonly used for local area networking of devices and Internet access, allowing nearby digital devices to exchange data by radio waves.
- **LoRa**
The LoRaWAN® specification is a Low Power, Wide Area (LPWA) networking specification designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks.

Multi-Network Interoperability/Integration

Finally, there's the way multiple networks of devices communicate, for example, how a building management system (BMS) integrates with a lighting/control system, or the way a lighting system communicates with an external system, such as an electricity provider for demand response. The most common approaches include:

- **Application Programming Interface (API)**
An API is essentially a mechanism for two or more computer programs or components to communicate with each other. These can be proprietary or open (Project Haystack and Brick are exam-

ples of the latter). This approach is typically used to 'bridge' systems where data from one can be used in the other. A common example is the integration of lighting control data and systems with HVAC data and systems.

- **OpenADR**
OpenADR is an open, highly secure, two-way information exchange model that standardizes the messaging format used for automated demand response so that dynamic signals can be exchanged between electricity providers and building control systems.
- **BACnet/Modbus**
BACnet and Modbus are communication protocols for building automation and control (BAC) networks, developed for communication between building systems such as heating, ventilating, and air-conditioning control (HVAC), lighting control, access control, and fire detection systems and their associated equipment.
- **KNX**
KNX is an open standard for commercial and residential building automation, to provide two-way communication between building systems such as lighting, window coverings, HVAC, security systems, energy management, and more.

Stacking/Layering Tiers of Interoperability

Layering different levels or types of interoperability can bring different benefits depending on the use case or the project objectives. Let's take a look at how this can work from the stakeholder's perspective, progressing through the lifecycle of a project and the different stakeholders involved at each stage.

Designers

At the earliest stages of a project, the designer (whether lighting designer, controls designer, or collaboration) along with the project owner, will be most familiar with the project goals, and will be tasked with ensuring those goals are met in the design documents. For instance, a retrofit office project may have three primary goals: the ability to reconfigure space depending on tenant needs, providing tunable white capabilities for occupants; and providing capabilities for integrating the existing HVAC system with the lighting control to provide occupant-responsive temperature control. In a project like this, the designer will first design network interoperability, to capture the first two goals, and then layer on multiple network interoperability to capture the

third goal, HVAC integration. By including network interoperability, the designer will be able to choose from a range of component devices, perhaps selecting tunable white devices from one manufacturer to achieve the second goal while selecting occupancy sensors from another manufacturer because the feature set is preferred. By layering on multi-network interoperability, the designer can then leverage the occupancy sensors to incorporate temperature control via thermostat in primary project goals. This can improve energy performance significantly, with increased savings ranging from 17-24%.

Installer

Interoperability benefits to the installer occur at the initial installation as well as any future upgrades, additions or replacements. Device level interoperability will streamline the initial installation significantly; for example, an outdoor controls project using either the Zhaga or NEMA connection standards will reduce the amount of time needed to install control devices on luminaires. Typically, an installer will only need to attach the control device and twist to secure before moving on to the next luminaire. Similarly, if a replacement is needed in the same application, the replacement can be done without removing or opening the luminaire. Network level interoperability layered on, benefits the installer as well. Consider the same outdoor controls project, consisting of phases installed over a period of months or even years. The installer can utilize any compatible control device, regardless of manufacturer, in subsequent phases or as replacement devices in the original phase. This can reduce the needed inventory the installer must carry as well as reduce service calls, as the installer can maintain a modest supply on the truck for faster response time.

Owner/Operator

Interoperability benefits to the owner/operator occur at every stage of the project. Stacking device and network interoperability ensures the owner's financial investment will be safeguarded both at the initial installation phase as well as throughout the lifecycle of the project. Initially, the device interoperability means that installation costs will be reduced, while network interoperability ensures that future expansions or replacements will be achieved in a cost-effective manner. Layering additional interoperability, such as multi-network, offers additional energy savings by enabling in-

tegration of occupant-responsive control over both lighting and HVAC systems. Similarly, providing OpenADR or API functionality can offer a portfolio owner/operator additional opportunities to manage energy performance or integration with other buildings' systems such as shading or smart glass. Consider a property management firm with a portfolio of commercial office properties in the Southwest and southern California. Leveraging all the layers of interoperability will enable the management team to maintain a real time view of each property's lighting system for predictive maintenance. Scheduling service calls for device or driver failure will be streamlined and simplified, since the service crew can choose from any available compliant device, rather than having to order specific proprietary items. Similarly, the central management team can coordinate upgrades or expansions of multiple properties to pre-commission luminaires from a single factory location and reduce installation time accordingly.

Occupants

Occupants are the ultimate beneficiary of the investment in interoperability, as they are not directly involved in the design or build phases of the project. Their productivity, ability to adjust lighting and temperature controls more easily and intuitively, are the direct result of the connectivity gained through interoperable design and performance. A 2018 survey of 7,000 Staples employees revealed that 80% of the respondents said that having good lighting in an office was essential. One-third said they would be happier at work if they had better lighting [8].

Conclusion

The benefits of interoperability are numerous:

- Flexibility in choosing network components, including luminaires, drivers, control devices
- Flexibility for the future in adjusting NLC performance to meet changing needs
- Simplified scalability for multi-phase projects or budget-conscious applications
- Effective insight into network operation for predictive maintenance, energy reporting, occupancy monitoring, demand response and more
- Integration between building systems like lighting, HVAC, access control and more

- Enhanced energy performance energy savings
- Improved occupant satisfaction and productivity

While many of these benefits can be realized from intentionally including interoperability into a project design and execution, this paper demonstrates that these benefits increase exponentially when a project team layers tiers of interoperability. Starting with foundational device interoperability ensuring swifter installations; adding network interoperability captures the forward-looking flexibility that owners and operators find vital. Adding multi-network interoperability achieves the full range of benefits possible.

It's becoming easier than ever to ensure all the stakeholders can realize some or all of the benefits described above. Industry consortiums like Bluetooth, Zhaga, and DALI Alliance continue to certify growing numbers of products that comply with open standards. Educational offerings—either in person at conferences and workshops or online via education platforms—make it easier than ever to gain an understanding of the principles of interoperability and how to incorporate it into an NLC project. The future of interoperability continues to expand and the marketplace as a whole will benefit. ■

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mwConnect: An American company based in Sacramento, mwConnect has produced superior lighting controls and related electrical power and protection components for 40 years. Today, mwConnect is engineering IoT solutions for today's rapidly changing marketplace. As an award-winning solutions provider with advanced design and manufacturing facilities in strategic global locations, mwConnect offers the most comprehensive wireless mesh solutions available in the marketplace. The company continues to support its long-time OEM partners with an extensive and essential lighting component product portfolio.



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Micro-optics: Shaping the Future of High-Performance LED Lighting

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Jessica van Heck holds an engineering degree from the University of Applied Sciences and has nearly 15 years of experience in the photonics industry, fostering innovation and collaboration. As the COO of PHABULOuS, a non-profit organization dedicated to advancing the micro-optics industry, she focuses on showcasing the potential of advanced free-form micro-optics and connecting customers with Europe's supply chain.

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The LED lighting industry is increasingly adopting advanced free-form micro-optics. These miniature optical structures enable precise light control, improve efficiency, and enhance overall LED lighting performance.

As industries demand higher performance and energy efficiency, micro-optics have become an essential element in modern LED lighting applications. In this series, we explore the advantages of micro-optics and the various manufacturing methods used to create them. In this first article, we focus on the core benefits of free-form micro-optics.

Reducing size and weight

Free-form micro-optics enable highly integrated and compact optical solutions. By shaping and directing LED light with extreme precision, they reduce the need for bulky lens arrays and reflectors, minimizing the size and weight of the lighting system. This is particularly valuable in automotive lighting, (wearable) consumer electronics, and LED-based medical devices.

Better illumination uniformity and glare reduction

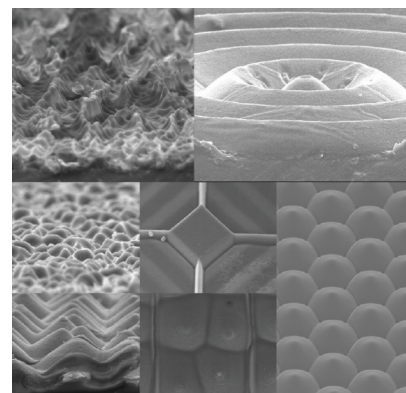
Free-form micro-optics also enable precise control over light distribution, allowing designers to shape beams more effectively than traditional optics. This results in better illumination uniformity, reduced glare, and the ability to create custom lighting profiles for specific applications, such as automotive headlights, architectural lighting, or streetlights.

Improved system efficiency

By directing light exactly where it's needed, free-form micro-optics optimize light pathways, thus requiring less power to achieve the same brightness level. This is crucial for battery-powered devices to reduce energy consumption. Moreover, by minimizing internal reflection and light scattering, these systems generate less heat, reducing the need for active cooling or large heat sinks.

Enhanced aesthetic & functional flexibility

Traditional LED optics, such as simple lenses and reflectors, can only produce basic beam patterns (e.g., circular, elliptical). Free-form micro-optics, however, allow for highly complex, non-symmetrical, or multi-zone beams. For instance, modern buildings and urban spaces often require customized lighting effects that are both aesthetic and functional. Free-form micro-optics help achieve soft gradient wall-washing effects for museums and art galleries, asymmetric streetlight beams that reduce glare in urban areas and dynamic façade lighting that adapts to environmental conditions.



Micro-optics come in various shapes and forms depending on the application and required light distribution.

Conclusion

As industries push for more sustainable and high-performance lighting, integrating micro-optics will play an increasingly crucial role in delivering innovative solutions. In upcoming articles, we'll explore real-world applications and cutting-edge technologies driving the future of LED lighting. ■



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ADVANCED MICRO-OPTICS FOR DOWNLIGHTS

Advanced micro-optics offer significant advantages for downlights by enabling precise control over light distribution, maximizing efficiency, and enhancing visual comfort.

- **Highly customized beam shaping** ensuring uniform illumination while minimizing glare and unwanted light spill. This flexibility is particularly valuable in architectural and commercial lighting, where tailored beam profiles can improve ambiance, highlight specific areas, and reduce energy consumption by directing light exactly where it is needed.
- **Enhanced optical efficiency** by reducing the number of components required, leading to thinner, more compact luminaire designs without sacrificing performance. These advancements enable more sustainable and aesthetically pleasing lighting solutions that optimize both functionality and design.

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Gallium Nitride (GaN) Technology Brings Efficiency and Size Benefits to LED Lighting Market

Denis Marcon, General Manager of Innoscience

Small changes can lead to significant impact. Even seemingly minor reductions in power consumption within a single household can translate into substantial energy savings when multiplied across millions of homes nationwide or globally. Take LED drivers, for example. According to the International Energy Agency (IEA), approximately 50% of global residential lighting sales now utilize LED technology⁷, making it the dominant lighting solution. This share is expected to grow further as the world moves toward decarbonization and Net Zero Emissions targets by 2050. The total number of LED drivers needed to support this expanding market depends on factors such as lighting arrangements and brightness requirements. However, one thing is clear: the demand will be enormous. If we can improve driver efficiency by even a few watts per unit, the cumulative energy savings on a global scale will be immense.

Efficiency isn't just about reducing power consumption—it also enables smaller, more compact devices. Gallium nitride (GaN) power ICs are revolutionizing LED drivers, delivering up to 4% greater efficiency than their silicon MOSFET-based predecessors while also being smaller and sleeker.

GaN has transformed power electronics. Its Figure of Merit (FoM)—defined as on-resistance (R_{on}) multiplied by gate charge (Q_g)—is ten times better (lower) than the best silicon MOSFETs. This allows systems to switch at much higher frequencies without compromising efficiency, enabling the use of smaller passive components (though EMC considerations remain important). Additionally, GaN has no body diode and, therefore, no reverse recovery current, which further enhances efficiency and simplifies circuit design, making totem-pole bridgeless PFC a viable and effective topology (**Figure 1**).

LED Driver Reference Design with GaN Technology (200W)

Reference designs produced by Innoscience shows the innovation. **Figure 2** compares a typical 120W silicon-based LED driver, versus a 200W unit made with GaN.

The topology of the GaN unit (boost PPC plus LLC), featuring GaN on the primary side, reduces component count, yet delivers 67% more power. The GaN LED driver requires 35% less PCB space and is 57% lower in profile than a typical silicon solution. Efficiency increases to 96%. The solution is implemented using three 650 V Innoscience HEMTs: one INN650D140A rated at 140 mΩ in the PFC stage, and two 240 mΩ INN650D240A devices for the LLC side – all packaged as 8 x 8mm DFNs.

It's worth noting that in the PFC stage, normally a silicon device would switch at 80 kHz, with GaN it is 140 kHz. And then, in the LLC portion of the circuit, MOSFETs would typically switch at 100 kHz, whilst in the Innoscience devices that switching speed has been trebled to 300 kHz. That is the trick to making the LED driver unit thinner, smaller and more powerful. As we have mentioned, EMC filtering needs to be addressed, but no large capacitors or chokes are required, as can be seen from the board dimensions (196 x 35 x 13mm). Not only is the GaN LED driver more efficient with a smaller footprint and lower profile, it also weighs less because no thermal potting material (the black sections of the silicon-based unit in **Figure 2**) is required. This also simplifies production since one process, which requires close control to avoid voids, is completely removed.

LED Driver Reference Design with GaN Technology (120W)

Figure 3 details another Innoscience reference design, this time for a 120W LED driver.

This again uses Innoscience's 650 V parts: the 350 mΩ INN650DA350A switching at 100–260 kHz, packaged in a 5 x 6mm DFN for the PFC stage; and the 240 mΩ INN650D240A GaN HEMT in the QR-flyback solution, switching at 120 kHz, packaged as an 8 x 8mm DFN. By comparison, silicon MOSFETs used in this application would typically switch at 60–180 kHz and 80 kHz.

By using GaN at these higher frequencies, the PCB length has been reduced from 255 mm in a commercially-available leading silicon-based design, to just 112 mm. Further benefits, including reduction in overall PCB area, reduction in size of transformer,

⁷<https://www.iea.org/energy-system/buildings/lighting>

and the elimination of heatsinks and thermal paste are detailed in **Table 1**.

Moreover, in this design, efficiency has been increased from between 88-90% in the silicon MOSFET design, to 93-94% with the GaN implementation. That increase in efficiency of around 4% works out at something like 4W for this 120W design. As we said at the top of this article, that may not seem like much, but if you multiply it by many times per household and then again for the number of households in a large city, or even country, the savings are very significant.

As well as efficiency, we have discussed size a good deal in this evaluation. Size is actually very important to the LED lighting driver market, as shown in **Figure 4**.

With a silicon product the driver will extend too far, or have a profile that is too thick - the GaN solution is much more suitable.

One of Innoscience's strengths is its portfolio of GaN solutions – by far the widest in the industry, including discrete, integrated and bidirectional devices (**Figure 5**). This includes devices that are offered in a number of package styles. For example, the reference designs in this article were achieved using GaN HEMTs in the DFN package. However, Innoscience also offers the same parts in the DPAK or TO252 package, which is favored by many LED lighting companies because it is very well suited for wave soldering and mass production. This is just one of the reasons why Innoscience HEMTs are already being used in volume by a number of producers.

Summary of GaN Technology for Lighting Applications

Gallium Nitride (GaN) technology is revolutionizing lighting applications by offering higher efficiency, improved thermal performance, and enhanced power management compared to traditional silicon-based solutions. GaN is a wide-bandgap semiconductor that allows for higher voltage, faster switching speeds, and reduced energy losses, making it ideal for LED drivers and power electronics in lighting systems.

As GaN technology continues to evolve, it is expected to play a key role in next-generation lighting solutions, enabling brighter, more efficient, and longer-lasting LED systems for various industries. GaN-on-Silicon (GaN-on-Si) technology is a semiconductor innovation that enables

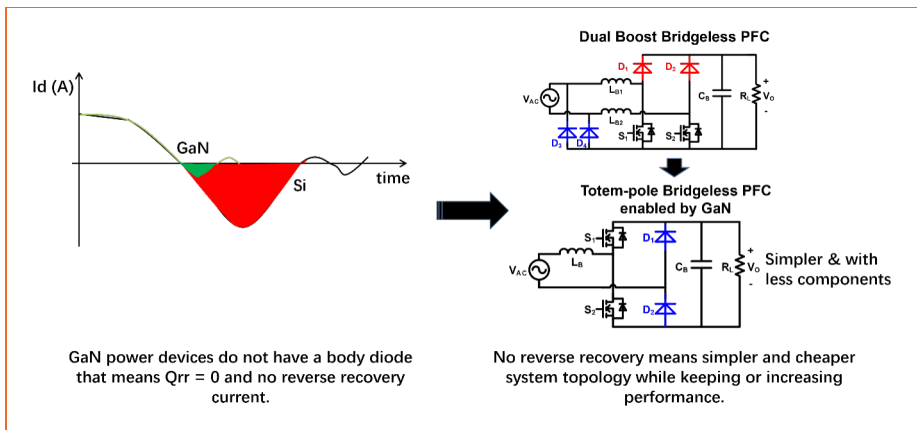


Figure 1: GaN has no body diode and therefore no reverse recovery current, increasing efficiency and enabling the use of simpler topologies such as totem pole bridgeless PFC.

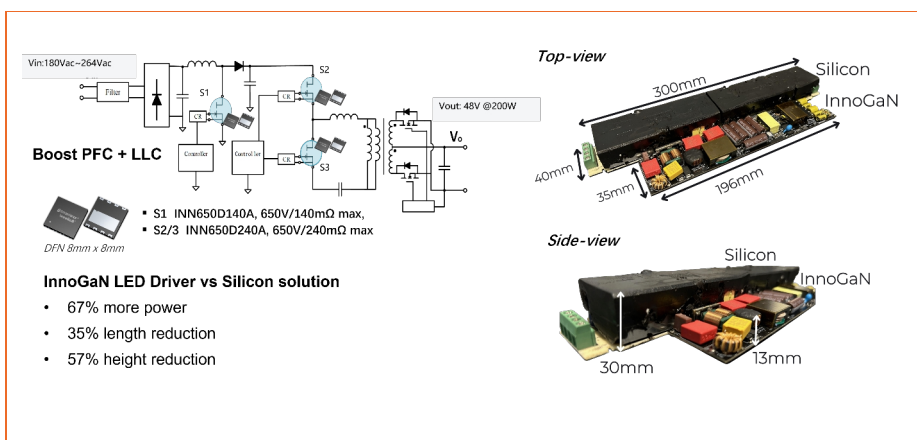


Figure 2: Comparison of a typical 120W silicon-based LED driver, versus a 200W unit made with GaN.

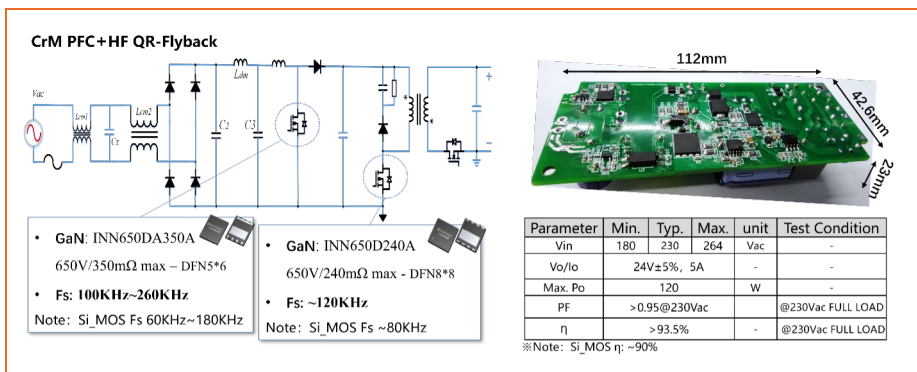


Figure 3: Innoscience reference design of an LED driver.

Component	Commercial Si solution	InnoGaN solution	InnoGaN advantage
PCB length	255mm	112mm	PCB length reduce 50%
Transformer	380uH	280uH	Size reduce 27%
PFC inductor	600uH	350uH	PCB area reduce 25.5%
PFC switch	500V/8A - VDMOS - TO220F	650V/350mΩ - InnoGaN - DFN5+6	Low loss - no heatsink
QR switch	650V/260mΩ - SJMOS - TO220F	650V/240mΩ - InnoGaN - DFN8+8	Low loss - no heatsink
Glue	200g	None	No glue - Weight reduce 60%+
Heat sink	2 PCS	Thermal Pad on partial of PCB bottom	No heatsink - weight reduce 40g
Peak Efficiency	89.95%	93.92%	4% higher efficiency

Table 1: Benefits and comparison of GaN designs on component level.

Gallium Nitride (GaN) devices to be manufactured on silicon substrates, combining the superior performance of GaN with the cost-effectiveness and scalability of silicon.

Applications in Lighting:

- LED Drivers – GaN-based drivers offer more efficient power conversion for commercial and residential LEDs.
- Smart & Connected Lighting – Faster switching and integration with IoT systems improve lighting automation.
- Automotive & High-Power LEDs – GaN enhances performance in headlights and high-intensity lighting.
- UV & Specialty Lighting – Used in high-power UV-C applications for sterilization and industrial processes. ■

About Innoscience

Innoscience (stock code: 02577.HK) is the leader of the global power semiconductor revolution and the world's largest gallium nitride chip manufacturer. Its product design and performance are at the international advanced level. The company's gallium nitride products are used in various low, medium and high voltage application scenarios. The product research and development range covers 15V to 1200V, covering wafers, discrete devices, ICs, modules, and providing customers with full gallium nitride solutions.

As of December 10, 2024, it has 406 patents and 387 patent applications worldwide. The products can be widely used

in cutting edge fields such as consumer electronics, automotive electronics, data centers, renewable energy and industrial applications. Innoscience, GaN creates a bright future for chips!

For more information visit the following websites: www.innoscience.com



Denis Marcon received a M.S. degree from the University of Padova in 2006. In 2011, he received the degree of Doctor in Engineering (Ph. D.) from the Catholic University of Leuven and Imec with a thesis entitled "Reliability study of power gallium nitride based transistors". Denis is the leading author or co-author of more than 50 journal papers or international conference contributions.

After his Ph.D. graduation, Denis has led projects aiming to develop GaN HEMTs for several applications (RF and power switching). Thereafter, he joined the business development team of Imec where he was directly responsible for the partnerships with Imec in the field of GaN power electronics as well as on dedicated development and manufacturing of Si-based devices, MEMS, sensors and micro-systems.

Denis is General Manager of Innoscience Europe (a subsidiary of Innoscience), and he is directly responsible for the Innoscience's GaN business and marketing in Europe.

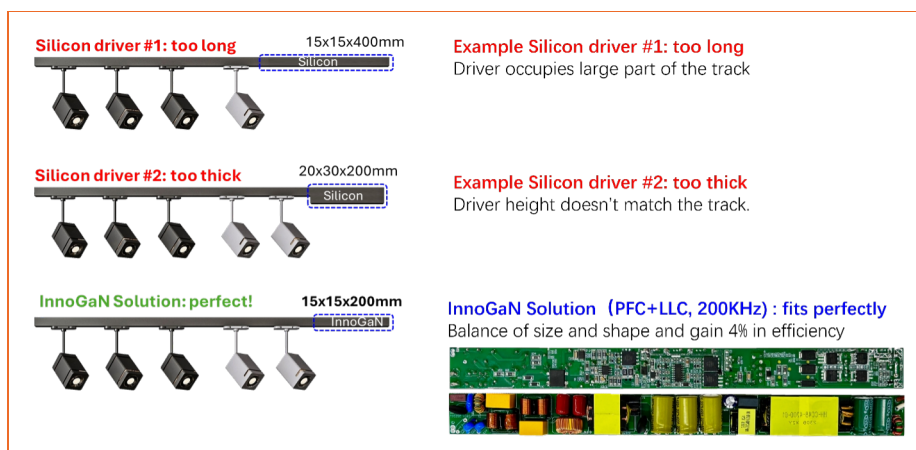


Figure 4: Size is actually very important to the LED lighting driver market.

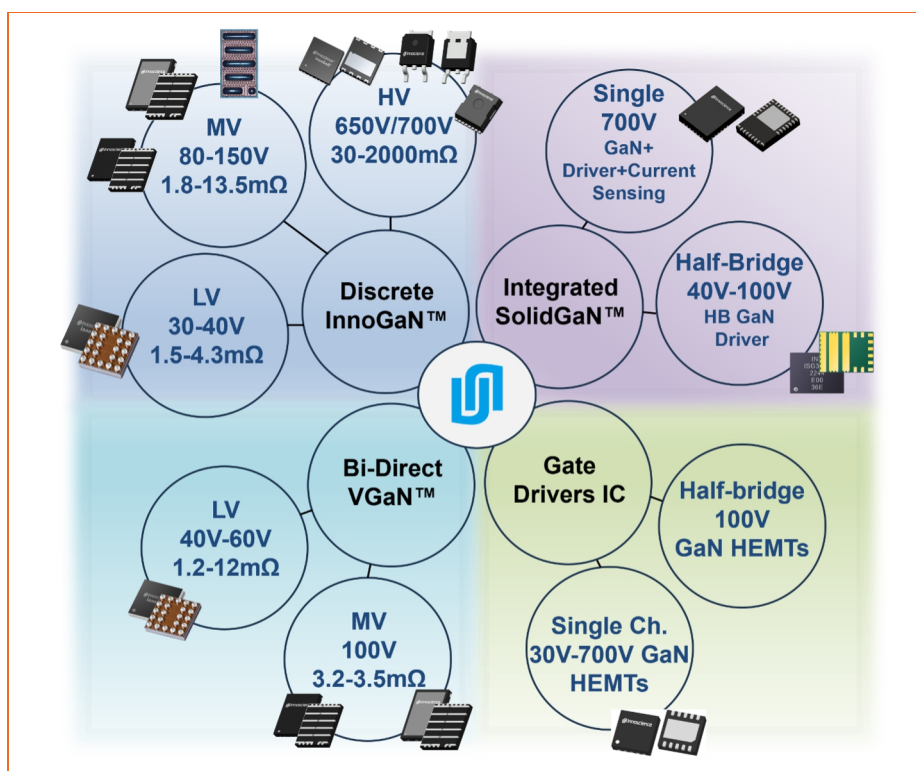


Figure 5: Innoscience's GaN portfolio.

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Expert Talks on Light – LUMILEDS

Exploring Innovation in Lighting: Advanced Solutions for High-Density Multi-Color LED Arrays and Revolutionary Automotive Body Illumination.

Talk#1: Challenges and Solutions when Designing Large Cluster Multi-color LED Sources



<https://youtu.be/mqfKDY1gDOQ>

Rob Engelen's presentation delves into the challenges and solutions for designing high-density, multi-color LED arrays for applications such as architectural, stage, and studio lighting. The presentation emphasizes achieving optimal light output, color mixing, thermal management, and compact LED packaging to meet modern lighting demands. A central focus is resolving conflicting design requirements, such as the preference for large LED dies to maximize light performance versus the need for small packages to ensure close-packing of LEDs.

To address these challenges, the presentation discusses advanced technologies. For thermal management, heat dissipation solutions include the use of innovative PCB substrates such as ceramic, insulated metal substrates (IMS) with copper pedestals, and advanced heat sink designs. These designs enable high drive currents, efficient heat transfer, and reduced noise by eliminating fans. Electrical routing is optimized using a three-stripe footprint to enable compact, efficient layouts while enhancing color mixing through better randomization of individual colors.

For more information visit:
<https://www.lumileds.com/>

Talk#2: Expanding the Horizons of Car Body Lighting



<https://youtu.be/KM1da8LihY>

Dr. Thorsten Anger's presentation, "Expanding the Horizons of Car Body Lighting," highlights innovations in automotive lighting design, emphasizing cutting-edge technologies that balance styling, functionality, and market feasibility. It explores diverse applications, including singular lit elements, backlit surfaces, and three-dimensional illuminated structures, tailored to unique vehicle designs.

The presentation identifies challenges in adapting advanced lighting technologies, typically reserved for high-end vehicles, to mainstream platforms. Lumileds addresses this with scalable, modular solutions that prioritize efficiency, cost-effectiveness, and sustainability. Key innovations include the LUXEON Versat 2016 LED Family for customizable brightness and spectral tuning, Dynamic Signature Lights with 192 individually addressable pixels for dynamic styling, and the LUXEON 3D LED Series, a flexible solution for slim, elongated designs. The Coin Concept Design introduces modular, efficient single-emitter solutions optimized for safety and easy integration.

Advanced technical features like collimator lenses, diffuse film covers, and optimized geometries enhance luminous efficiency and uniformity, catering to large, curved surfaces while ensuring high-performance optical quality. Lumileds' focus on sustainability is evident through recyclable materials and automated, modular integration systems designed for mass production.

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Challenges and Solutions when Designing Large Cluster Multi-Color LED Sources

by Rob Engelen, Director of LED Applications Engineering at Lumileds

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Challenges and solutions when designing large cluster multi-color LED Sources

Rob Engelen
Director of LED Applications Engineering




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Expanding the Horizons of Car Body Lighting

Dr. Thorsten Anger, Product Manager 3D LED & MxN at LUMILEDS

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- 16.10 Presentation by Dr. Renske Lok
- 16.30 Presentation by Dr. Jeffrey Hubbard
- 16.50 Panel discussion



Dr. Virginie Gabel



Dr. Renske Lok



Dr. Jeffrey Hubbard



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PREVIEW*

May/June 2025 | LpR 109

Lighting Outlook

The May/June 2025 edition covers the latest topics from the lighting industry and design world. We feature an exclusive interview with the Zhaga organization, discussing current trends and key areas of future standardization. Additionally, we provide an early insights into the latest innovations showcased at LightFair International, taking place in early May. This issue will also highlight the DALI Awards 2025, showcasing the winning projects across various categories. Of course, we continue our in-depth technology reports on LEDs and their applications. Dr. Octavio L. Pérez is a co-author, together with other medical researchers at Mount Sinai Hospital, of the paper entitled "The Impact of Dynamic Lighting on Sleep Timing and Duration for Hospitalized Patients", that has been accepted for publication in the "Journal of Sleep Research" (Wiley). Dr. Pérez will give us insights about the interesting multidisciplinary study behind the paper. A leading expert's commentary, along with the latest International Lighting News, completes this edition.

* *Subject to change without notice.*

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